

A GROSS, HISTOLOGIC AND
HISTOCHEMICAL STUDY OF THE EYE
ADNEXA OF SHEEP AND GOATS

Thesis for the Degree of Ph. D.
MICHIGAN STATE UNIVERSITY
Ram Das Sinha
1965

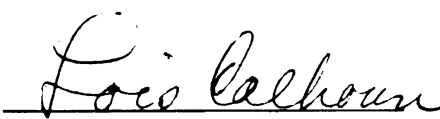
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Ram Das Sinha

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Ph.D. degree in Anatomy


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ABSTRACT

A GROSS, HISTOLOGIC AND HISTOCHEMICAL STUDY OF THE EYE ADNEXA OF SHEEP AND GOATS

by Ram Das Sinha

As a result of the increasing importance of experimental ophthalmology and inadequate knowledge of the gross anatomy, histology and histochemistry of the eye adnexa of sheep and goats, the present investigation has been undertaken.

For the histologic study, the eye adnexa of 8 male sheep, 2 weeks to 5 months old; 8 female sheep, 3 months to 4 years old, and 4 male goats, 5 days to 5 months old were obtained. In addition to the heads of these animals, 4 heads of female sheep, 3 to 4 years old were used for the gross anatomy. For histochemical study frozen specimens from 2 sheep, 2 months to 2 years old and 2 goats, 5 days old, and in addition, paraffin sections from all the animals used for histology were processed.

Ten percent formalin fixed and latex injected specimens were dissected for gross study. For the study of the course of the lacrimal drainage passage and orbital blood vessels, injections of radiopaque substance (barium sulphate) were employed. For the detailed study of the blood vessels of the adnexa, India ink injection technique was used.

The following stains were used for the histologic study:

(1) Harris hematoxylin and eosin, (2) Weigert and Van Gieson's stain, (3) Mallory's triple stain, (4) Gomori's reticular stain, and (5) Modified Bielschowsky Gros silver stain.



For the histochemical study paraffin sections were stained with (1) Alcian Blue and Nuclear Fast Red, (2) Toluidin Blue and (3) Periodic acid Schiff (PAS) reagent. Frozen sections were treated with (4) Sudan Black, (5) Nile Blue Sulfate, (6) Naphthal As-BI and Phosphoric acid and (7) Naphthal As-Mx and Phosphoric acid.

The following observations were made in the eye adnexa of sheep and goats: Eyebrows are represented by a few supercilia and some sensory hairs. The medial palpebral commissure of sheep is unpigmented and grooved leading to the lacrimal (infraorbital) pouch which contains large multilobulated sebaceous glands. The lacrimal pouch is absent in goats. Muscles of Müller and Riolan are well developed. The conjunctival epithelium is variable being stratified squamous at some places, stratified cuboidal to columnar at other places and occasionally transitional. Goblet cells and varying number of lymphocytes and lymph nodules are present in the conjunctiva. Lymph nodules are more numerous in sheep. The post-tarsal conjunctiva of goats contains epithelial "buds." The limbal conjunctiva lacks Manz glands but always contains an epithelial thickening, a few rete pegs and some pigment granules. The caruncles of sheep are microscopically similar to those of goats. The deep nictitans (Harderian) gland is absent in both. The superficial nictitans gland is a mixed gland: tubuloalveolar in sheep and compound tubuloalveolar in goats. The PAS reagent and Alcian Blue reveal the presence of mucous and serous glands. The periorbita, orbital fascia and extrinsic ocular muscles are similar. Microscopically the lacrimal glands resemble the nictitans glands. Many plasma cells are present in the nictitans and lacrimal glands. Six or seven lacrimal excretory ducts are present in both and are lined with stratified columnar epithelium having many goblet cells.

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in both species. Connective tissue septa of the lacrimal gland of sheep contain some smooth muscle fibers. Lacrimal canaliculi are lined with stratified squamous epithelium near the puncta and stratified columnar near the lacrimal sac. Lacrimal sacs and nasolacrimal canals are generally lined by stratified columnar epithelium containing varying numbers of goblet cells. At some areas pseudostratified epithelium is also observed. They are surrounded by a rich venous plexus. The lower third of the nasolacrimal ducts is surrounded by seromucous glands.

A GROSS, HISTOLOGIC AND HISTOCHEMICAL STUDY
OF THE EYE ADNEXA OF SHEEP AND GOATS

By

Ram Das Sinha

A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

DOCTOR OF PHILOSOPHY

Department of Anatomy

1965



VITA

Ram Das Sinha

Candidate for the degree of
Doctor of Philosophy

Final Examination: January 12, 1965. 9:00 a.m.

Dissertation: A Gross, Histologic and Histochemical Study of
the Eye Adnexa of Sheep and Goats.

Outlines of Studies:

Major Subject: Anatomy

Minor Subjects: Physiology and Surgery and Medicine

Biographical Items:

Born: January 2, 1927. Parents: B. Bishundhari singh and
Smt. Dhanmato kunwar.

Chamanbigha, Jehanabad, Gaya, Bihar, India.

Undergraduate Studies: I. Sc., Science College, Patna, 1948.
G.B.V.C., Bihar Veterinary College,
Patna, 1951.

Graduate Studies: M. S., Michigan State University, 1964.

Experiences:

Touring Veterinary Surgeon, 1951.

Demonstrator in Anatomy, B. V. College, Patna, 1951-1954.

Lecturer in Anatomy, B. V. College, Patna, 1954-1962.

Assisted in teaching Anatomy, M. S. U., 1962-1963.

Research, Michigan State University, 1962-1965.

Editor (Hindi section) "Bihar Veterinarian," 1958-1962.

Member of: Bihar Veterinary Association and Phi Zeta (a national
honor society of Veterinary Medicine)

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ACKNOWLEDGMENTS

The author wishes to express his deep and sincere appreciation and thanks to Dr. M. Lois Calhoun, Professor and Head of the Department of Anatomy and Chairman of the Guidance Committee, for her constant supervision, guidance and encouragement throughout the course of the investigation and higher studies. He wants to record his grateful thanks to Dr. C. W. Titkemeyer, Dr. T. W. Jenkins, Dr. R. Brown, Dr. E. M. Smith, Dr. A. W. Stinson, Mr. R. Carrow, and Dr. E. H. Roege for their continuous suggestions, inspiration and help. He is grateful to Dr. W. D. Collings, Professor of Physiology and Pharmacology, and Dr. G. H. Connor, Professor of Surgery and Medicine for sparing their valuable time for serving on the Guidance Committee and giving valuable advice. The writer wishes to thank Dr. R. A. Fennell, Professor of Zoology for his help and advice in histochemical preparations and Dr. U. V. Mostosky, Assistant Professor of Surgery and Medicine for his help in radiography. Special thanks are extended to Mrs. Jan Sharon and Mr. Carl Oehling for their technical assistance, Mrs. Luella Wahl and Mrs. Mae Suit, secretaries, for their typing assistance, and all members of the Anatomy Department and friends for their beneficial suggestions.

Finally, the author's sincere gratitude goes to his wife Smt. Phulmati Devi, his brothers: Sri Ram Dahin Singh and Sri Ram Prasad Singh, and the officials of the Government of Bihar, India for their enthusiastic inspiration and help in diverse ways to make this higher education a reality.

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INTRODUCTION

The present investigation on the eye adnexa of sheep and goats was undertaken for many reasons:

The importance of veterinary ophthalmology is increasing rapidly. The recent investigations of Catcott (1952), Magrane (1951, '55, '57, '59), Smythe (1956) and others have given impetus to this area of research. Sound knowledge of ocular anatomy provides a basis for a better understanding of ocular physiology, pathology and clinical medicine and surgery.

Extensive literature on the anatomy of the human eye is available but comparatively little work has been done on the eye of domestic animals, especially sheep and goats.

Occurrence of eye cancer is generally found associated with the accessory structures of the eye such as eyelids, nictitating membrane, caruncle and conjunctiva.

There is a considerable controversy regarding the presence or absence of the following structures in various mammals: the Harderian gland, the smooth muscle fibers in the nictitating membrane and the Manz glands of the conjunctiva.

Among laboratory animals used for experimental ophthalmology, the sheep is unique in that its lacrimal artery can be approached without entering the orbit.

While the chemical nature and functional activities of the ocular glands of many laboratory animals and man have been examined histochemically, no similar technique has been applied to the eye of sheep and goats.

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REVIEW OF LITERATURE

An extensive survey of the literature revealed that knowledge of the comparative anatomy of the eye of domestic animals is still incomplete. Standard books of veterinary anatomy include very little information on the gross and microscopic structures of the eye of sheep and goats. In "The Anatomy of Domestic Animals" by Sisson and Grossman (1953), a complete description of the eye is given only for the horse and comparatively little or none for the other domestic animals. Even specific books like "Anatomy and Histology of the Eye and Orbit in Domestic Animals" by Prince et al. (1960) and "Fundamentals of Histology of Domestic Animals" by Trautmann and Fiebiger (1957) are insufficient regarding the eye adnexa of sheep and goats.

EYEBROWS

Gross - Eyebrows are not confined to the primates only. Cat eyebrows are represented by a few long hairs. In man, the space between the two eyebrows usually remains smooth and hairless and hence called glabella (Wolff, 1955). Human eyebrows are transversely arched eminences of skin surmounting the orbit and supporting numerous, short, thick and comma shaped hairs (Boyd, 1956; Johnston et al. 1958). Their muscles are innervated by the facial nerve (Berens and Siegel, 1950).

Histology - In structure, the human eyebrows resemble the hairy scalp. The skin is thick, mobile and richly supplied with sebaceous glands. Fibers from the oricularis oculi, corrugator and occipitofrontalis muscles are inserted into the skin of the eyebrows (Boyd, 1956; Johnston et al., 1958).

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EYELIDS (PALPEBRAE)

Gross - Eyelids are present only in vertebrates. Except in some sharks, fishes lack eyelids or have only rudimentary immobile lids (Romer, 1962; Wolff, 1955). In amphibia the upper lid is immobile while the lower one is movable (Prince, 1956). In terrestrial animals the lids are better developed for cleaning and moistening the cornea, protecting the eyeball from external injury and helping the pupil to regulate the amount of light reaching the retina (Boyd, 1956). In reptiles there are many varieties of lids, thick and slightly mobile in cheleonians (turtles, tortoise), thin and usually the lower one mobile in lizards and a transparent movable lower lid in serpents. In birds the lower eyelid is far more mobile than the upper one (Wolff, 1955), but in mammals the reverse is true (Prince, 1956). The upper lid is shorter in cats and longer in horses. The eyelids of the ox are quite thick and tougher than those of horses. In sheep they are comparatively thinner than those of swine and goats (Prince, 1956; Prince et al., 1960).

Gross anatomy of the eyelids has been described by Chauveau (1891), Ellenberger and Baum (1943), Prince et al. (1960) and Sisson and Grossman (1953) in various domestic animals. Both lids are united on either side by corresponding lateral and medial palpebral commissures. The interval between the margins of the lid is called palpebral fissure or Rima palpebrum (Sisson and Grossman, 1953). The palpebral fissure of birds is circular (Nicolas, 1924). The ends of the fissure form corresponding lateral and medial angles or canthi. The lateral canthus is acute when the eye is opened, while the medial canthus is narrow and presents a depression called the lacrimal lake (Lacus lacrimalis) which lodges a small rounded pigmented eminence called lacrimal caruncle (caruncula lacrimalis). Each lid consists of two surfaces, external or cutaneous and internal or palpebral and a free border (Sisson and Grossman, 1953); Wolff, 1955). The free border

near the medial canthus presents a small papilla on which opens the Punctum lacrimalis. This border consists of two margins, anterior and posterior known as Limbus palpebralis anterior and posterior respectively. The anterior margin carries the eyelashes or cilia (Sisson and Grossman, 1953).

Each lid is composed of the skin, subcutis, muscular layer, tarso-fascial layer and palpebral conjunctiva (Sisson and Grossman, 1953; Trautmann and Fiebiger, 1957).

The skin is freely movable except at the free border and is covered by a dense coat of fine hairs and few tactile hairs (Prince et al., 1960; Sisson and Grossman, 1953). Tactile hairs are found scattered at the base of the lower lid of the horse (Prince et al., 1960), on the eyelids of the fetal pig (Fowler, 1962), on both eyelids of sheep (Prince et al., 1960) and goats (Prince et al., 1960; Sar, 1963). In swine the palpebral skin contains coarse and widely scattered hairs (Trautmann and Fiebiger, 1957). The skin of the free border is smooth and usually pigmented (Prince et al., 1960). Eyelashes are longer in the upper lid. Cilia of the lower eyelid are lacking in carnivores and swine (Trautmann and Fiebiger, 1957). Cilia of the upper lid number about 100 in horses and cattle and 30 in asses while the lower eyelid contains about 60 in cattle and 25 in asses (Prince et al., 1960). In birds the rudimentary feathers without barbs take the place of the eyelashes and tactile hairs (Nicolas, 1924). The subcutis is devoid of fat and intermingled with the muscular coat (Trautmann and Fiebiger, 1957).

The palpebral muscles vary in number and arrangements from one species to another. The orbicularis oculi is constantly found in all domestic animals (Sisson and Grossman, 1953). It is an elliptical muscle surrounding the palpebral fissure and attached laterally and medially by palpebral ligaments. At the medial commissure a slip is

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detached from the orbicularis oculi which passes medially behind the lacrimal sac and attaches to the orbital wall and is known as Pars lacrimalis or Harner's muscle (Prince et al., 1960; Sisson and Grossman, 1953). Other palpebral muscles which are constantly found are the aponeurosis of the levator palpebrum superioris in the upper lid and an aponeurotic slip of the inferior rectus in the lower lid. Both of these muscles are attached to the posterior part of the corresponding tarsi (Trautmann and Fiebiger, 1957). In addition to these muscles, the orbicularis oculi receives fibers from the corrugator supercilii in the horse and dog, and frontalis in the ox in the upper lid, and malaris in the lower lid. The malaris muscle is absent in pigs (Sisson and Grossman, 1953).

The tarso-fascial layer consists of an anterior fibrous plate (the tarsus) and the posterior fibrous membrane (the palpebral fascia or orbital septum). Human tarsi are semilunar in shape and the superior tarsus is larger than the inferior one (Woodburne, 1957). The ends of the tarsi are attached laterally and medially to the orbital wall by the lateral and medial palpebral ligaments respectively (Prince et al., 1960) and the convex borders of the tarsi are attached to the orbital septum (palpebral fascia) which is continuous with the periosteum at the superior and inferior margins of the orbit (Woodburne, 1957). Tarsal glands are embedded in the deep face of the tarsus and are arranged vertically to the free margin of the lids and parallel one another (Sisson and Grossman, 1953). The palpebral conjunctiva lines the internal surface of the lid and attaches firmly to the tarsus (Bedrossian, 1958).

The blood supply to the eyelid of the horse comes from the branches of the ophthalmic and facial arteries and the blood is drained by corresponding veins (Sisson and Grossman, 1953). In man, the eyelids are supplied by the branches of both facial and ophthalmic

arteries but in most animals chiefly by the malar artery which is a branch of the infra-orbital artery (Prince and Ruskell, 1960). Lymph vessels of the eyelids of the ox drain to the parotid lymph node (Sisson and Grossman, 1953). The sensory innervations to the structures of the eyelids are derived from the ophthalmic and the maxillary divisions of the trigeminal nerve. The motor nerves to the orbicularis oculi come from the facial nerve. The levator palpebrum superioris is supplied by the oculomotor nerve. The smooth muscle fibers (muscle of Müller) are innervated by sympathetic fibers (Prince et al., 1960; Sisson and Grossman, 1953).

Human eyelids develop as folds of integument adjacent to the eyeball (Arey, 1954). At the beginning of the second month each of the folds remains circular and hence the palpebral fissure is first rounded. After two weeks the upper and lower portions of the folds grow towards each other and thus angles (Canthi) are formed and the upper and lower eyelids are demarcated. Their edges meet and fuse loosely. At about the fifth month the epidermal union starts to separate through keratinization of cells and becomes completely separated at the seventh or eighth month (Wolff, 1955). In some mammals it is delayed until after birth (Arey, 1954). The cilia of rats (Fowler, 1962), and of men (Arey, 1954; Wolff, 1955) develop like ordinary hairs as epithelial buds from the fused lid margins, first on the upper lid and then on the lower lid. Glands of Moll and Zeis develop as outgrowths from the ciliary follicles. The tarsal (Meibomian) glands develop as ingrowths of a regular row of solid columns of ectodermal cells from the lid margins behind the posterior row of cilia (Wolff, 1955).

Histology - The palpebral epidermis of man contains all four layers (Wolff, 1955). In rats the epithelium is thin which becomes thick at the margin (Holmes, 1960). The stratum corneum is thin and the stratum germinativum is one layer thick in swine (Marcarian,

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1962). Abundant pigment granules are found in and between the cells of the stratum germinativum in cattle (Sinha, 1964). The dermis contains fine elastic and collagenous fibers in cattle (Sinha, 1964) and abundant elastic fibers and chromatophores in man (Bedrossian, 1958). The ordinary palpebral hairs are fine and are supplied with well developed sebaceous and tubular glands in Holstein cattle (Sinha, 1964). These hairs lack arrectores pilorum muscles in the rat (Holmes, 1960). Zeis glands are rudimentary sebaceous glands which open in the follicles of the eyelashes. Glands of Moll are modified sweat glands, some of which open in the ciliary follicles and others in front of the openings of the tarsal glands as tiny orifices (Prince et al., 1960). Tactile hairs lack arrectores pilorum muscles (Trautmann and Fiebiger, 1957). The subcutis is fat-free and contains loose areolar tissue (Wolff, 1955). The epithelium of the ciliary follicle in cattle becomes thickened near the nerve plexus (Goldsberry, 1965).

The muscle fibers of the orbicularis oculi are arranged in a concentric manner and at the palpebral margin some of them, which enclose the ducts of the tarsal glands, and ciliary follicles and the associated glands are known as muscle of Riolan (Prince et al., 1960). They are distinctly marked in cattle (Sinha, 1964; Trautmann and Fiebiger, 1957). Some smooth muscle fibers (Müller's muscle) are also found attached to the tarsus (Prince et al., 1960; Sinha, 1964).

The tarsus is less developed in domestic animals than in man. It is composed of dense collagenous tissue and is fused with the capsule of the tarsal gland. In the pig there is a secondary fibro-cartilagenous tarsus near the base of the lid (Trautmann and Fiebiger, 1957). The tarsus of man also contains some elastic fibers (Wolff, 1955). The lower lid of most birds except parrots contains a saucer-shaped cartilage (Nicolas, 1924). The tarsal (Meibomian) glands are

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the largest of the modified sebaceous glands. They open independently of the cilia on the ventral aspect of the lid margins. They are more numerous in the upper lid and variable in different species. Each gland has a central duct lined by simple cuboidal epithelium and is surrounded by numerous alveoli which open into it (Prince et al., 1960). The main ducts as well as the alveolar ducts are lined with stratified squamous epithelium in cattle (Sinha, 1964). The glands are larger in the upper lid than in the lower one. The secretion of the gland is fatty in nature which lubricates and smoothens the margin and prevents the overflow of tears (Trautmann and Fiebiger, 1957). In the rabbit, guinea pig, cat, dog, horse and primates, the sebaceous parenchyma of the Meibomian glands is surrounded by a plexus of nerve fibers which contain specific cholinesterase (Montagna and Ellis, 1959). The Meibomian glands in birds are absent and their place is taken by a pair of Harderian glands (Nicolas, 1924).

Histochemistry helps greatly to reveal the localization of chemical constituents within cells (Lazarow, 1962). Sweat glands in the bovine species are negative for fat lipids or cholesterol and their esters, whereas sebaceous glands are positive for these lipids and their esters. Bovine sweat glands do not contain glycogen and lipids which are present in human eccrine and apocrine sweat glands (Yang, 1952). Using histochemical stains, Ato (1961a, b) and Sinha (1964) found that sweat glands of cattle are apocrine. The presence of alkaline phosphatase and phospholipids in sebaceous glands was reported by Montagna and Hamilton (1947) in the hamster, by Montagna and Noback (1947) in rats and by Montagna et al. (1948) in man. The saccules of the Meibomian glands are filled with a fatty epithelium. The amount of secretion is so slight that only histochemical methods are suitable to investigate it (Krause, 1934). According to Krause, Pes (1898) reported that the secretion of the Meibomian gland contains

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mostly cholesterol mixed with a small quantity of fat and soaps caused by the action of alkaline tears on fat. Buschke (1905) increased the glandular secretion by means of eserine and obtained a milky emulsion of fatty substance and tears. He observed the secretion as a thick mass in the alveoli and tubules which gave a partial reaction of fat.

CONJUNCTIVA

Gross - The conjunctiva is a thick transparent mucous membrane lining the eyelid as the palpebral conjunctiva and reflecting upon the anterior part of the eyeball as the bulbar conjunctiva. The line of reflection is called the fornix conjunctivae (Sisson and Grossman, 1953). The palpebral conjunctiva is extended to cover the caruncle and membrana nictitans (Smythe, 1956). It may be further divided into the marginal, tarsal and orbital parts (Wolff, 1955). The palpebral conjunctiva is firmly attached to the tarsal plate while the bulbar conjunctiva is loosely attached to the underlying structures and thus the conjunctiva helps in the suspension of the eyeball anteriorly (Prince et al., 1960). The conjunctiva of the fornix is loosely attached and supero-laterally pierced by the orifices of the lacrimal excretory ducts (Prince et al., 1960). The ocular epithelium which lines the anterior part of the eyeball is subdivided into the sclerotic and corneal parts. The corneal part is purely epithelial and is regarded as the anterior layer of the cornea (Smythe, 1956). The conjunctiva covering the margin of the cornea is known as the sclero-corneal or conjunctival limbus (Nicolas, 1924). The bulbar conjunctiva at the sclero-corneal junction contains pigment (Sisson and Grossman, 1953). The conjunctiva develops from the ectoderm lining the inner surface of the lids, front half of the sclera and the entire cornea (Arey, 1954). The blood supply to the conjunctiva comes from the anterior ciliary artery (Prince and

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Ruskell, 1960). A lymphatic system is also present in the conjunctiva. The conjunctiva is innervated by the branches of the fifth cranial nerve. The corneal part is supplied by the ciliary nerves which are the efferent branches of the ciliary ganglion and contain sensory fibers from the ophthalmic division of the fifth nerve (Symthe, 1956).

Histology - The conjunctiva consists of two layers: the epithelium and substantia propria. The epithelium at the lid margin is stratified squamous. The number of squamous cells and cell layers is reduced behind the lid margin. At the tarsal region the conjunctiva is reduced to two layers of cells, superficially columnar and deeply cuboidal (Prince et al., 1960; Wolff, 1955). The palpebral conjunctiva of the horse is papillated and contains many goblet cells (Sisson and Grossman, 1953). At about the level of the tarsal glands the epithelium changes from stratified squamous to stratified columnar in the horse and carnivores or to transitional in the ruminants and swine (Trautmann and Fiebiger, 1957). The palpebral conjunctiva in man contains glands of Wolfring and glands of Henle (Wolff, 1955). The tarsal conjunctiva of the lower lid contains more cell layers. In the conjunctival epithelium at the fornix, a thin layer of polyhedral cells is added between the two cell layers and goblet cells increase in number (Prince et al., 1960). Only the horse has glands in this region (Trautmann and Fiebiger, 1957). The epithelial layers of the bulbar conjunctiva gradually increase to the limbus. The superficial cells become flatter and the deep ones cuboidal (Prince et al., 1960). At the limbus the epithelium is always pigmented (Trautmann and Fiebiger, 1957). The glands of Manz are saccular and are found at the limbus of the pig, ox, lamb, fox and dog (Prince et al., 1960; Wolff, 1955). According to Aureli and Kornerup (1949) the Manz glands are present in swine and absent in man. The presence or absence of the Manz gland in various animals has been so controversial

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that it was studied by many investigators such as Blumberg (1867), Terson (1893), Zietzschmann (1906) and others in different animals but still the problem is not solved. According to Aureli and Kornerup (1949), Strohmeyer (1859) reported the presence of the Manz glands in the horse, ox, sheep, pig, roedeer, fox and man. The bulbar conjunctiva lacks goblet cells (Prince et al., 1960). Sweat glands have been described in the bulbar conjunctiva of the goat, pig, and ox (Wolff, 1955).

The substantia propria consists of the superficial adenoid and deep fibrous layers. The superficial layer contains a network of fine connective tissue and lymphocytes. It starts as a thin layer at the subtarsal fold and becomes thick at the fornix (Prince et al., 1960; Wolff, 1955). At the fornix the propria contains deposits of lymphoid tissue which forms ridge-like prominences separated by grooves. The deep layer of the substantia propria contains thicker fibers and conjunctival blood vessels, nerves and some glands (gland of Krause). The substantia propria contains an abundance of elastic fibers in the horse, dog, ox, and cat. The lymphatic follicles which are absent in man, occur variably in the domestic animals. They are numerous in the ox and known as the "plaques of Brush"; arranged around the cornea in the horse; found more near the medial canthus and in the bulbar conjunctiva in the dog and more developed in the autumn and summer than spring in sheep (Nicolas, 1924). The substantia propria forms a few papillae at the limbus and the lid margin (Prince et al., 1960; Wolff, 1955). Three kinds of nerve endings: free endings, bulbs of Krause and tufts or ribbons are seen in the conjunctiva (Wolff, 1955).

Biochemistry and Histochemistry - According to Krause and Chan (1933) the principal conjunctival chemical constituents are protein (mucin, collagen, elastin, albumin, globulin); lipids (neutral

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fats, fatty acids, phospholipids and cholesterol); carbohydrates (glucose and lactic acid) and inorganic salts (sodium chloride and phosphates). The conjunctival secretion is slightly acidic, possibly due to calcium urate (Sanyal, 1931). Histochemically the presence of alkaline phosphatase, glycogen and some melanin has been observed in the conjunctiva. Mucin of the conjunctival goblet cells reacts weakly to metachromatic dyes and alcian blue but stains well by HIO_4 and CrO_3 Schiff procedures (Lillie, 1954).

LACRIMAL CARUNCLE (CARUNCULA LACRIMALIS)

Gross - The caruncle is a small, oval body generally pigmented in domestic animals (Prince *et al.*, 1960; Sisson and Grossman, 1953) and flesh coloured in man (Wolff, 1955). It contains a few small hairs. It is developmentally regarded as part of the lower eyelid (Arey, 1954).

Histology - It is covered by stratified squamous epithelium which contains goblet cells in the dog, pig and horse. The dermis contains leucocytes and in the dog, horse and ox, lymph nodules (Trautmann and Fiebiger, 1957). The caruncle also contains modified sweat glands and a few sebaceous glands which open into minute hair follicles. Some seromucous glands (accessory lacrimal glands) are also found in horses and carnivores (Trautmann and Fiebiger, 1957).

THE THIRD EYELID (NICITATING APPARATUS)

Gross - The third eyelid (palpebra tertia) is a fold of conjunctiva supported by a cartilage and situated in the inner canthus (Davis, 1929; Trautmann and Fiebiger, 1957). Developmentally it belongs to the conjunctiva (Wolff, 1955). It is absent in fishes except elasmobranchs in which it is represented by an adipose flap (Prince, 1956). It is well developed and very active in the frog and in birds and when stretched

it becomes transparent (Stibbe, 1928; Wolff, 1955). In birds and reptiles it contains two special muscles called the pyramidalis and the quadratus which are innervated by the 6th cranial nerve (Wolff, 1955). It is fully developed and active enough to sweep the whole cornea in ungulates but much less developed in carnivora and marsupials (Johnson, 1901). In all primates it becomes vestigial and is represented by the plica semilunaris (Prince et al., 1960). The third eyelid of the rabbit has no special muscle but it moves outward or inward due to the corresponding contraction or relaxation of the retractor oculi muscle. The levator muscle sends a slip to the base of the third eyelid which might control this movement (Davis, 1929).

The cartilage of the third eyelid is irregularly triangular in shape. Its wider and thinner part lies in the nictitating membrane; and the narrow, thicker portion medial to the eyeball is surrounded by the nictitating gland (Sisson and Grossman, 1953). Prince et al. (1960) described this cartilage as 'T' shaped. The cartilage is absent in birds (Stibbe, 1928; Trautmann and Fiebiger, 1957) and is rarely found in man (Wolff, 1955).

The glands of the third eyelid are classified by Trautmann and Fiebiger (1957) and Prince et al. (1960) into two groups: the superficial (nictitans) and deep (Harderian). The nictitans gland surrounds the cartilage (Trautmann and Fiebiger, 1957) and the Harderian gland is placed at the deep end of the cartilage (Davis, 1929). The presence of the Harderian gland was first reported by Harder (1694) in all mammals except some carnivores and primates. Loewenthal (1892) observed this gland in the mouse, rat, guinea pig, pig, calf, sheep, and horse. According to Giacomini (1887) as cited by Wolff (1955) the Harderian gland is present in all vertebrates, large in mammals, especially in herbivora, rudimentary in the lower apes but absent in

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the anthropoids, such as man. When the Harderian gland is well developed, the lacrimal gland is poorly developed and vice versa (Wiedersheim, 1898 cited by Wolff, 1955). It is rudimentary in amphibia and large in serpents and birds (Wolff, 1955). The Harderian gland of birds is situated at the back of the orbit and drains into the deep internal fornix of the third eyelid. In mammals the Harderian gland is situated in the substance of the nictitating membrane, covering the superficial aspect of the inner two-thirds of the deep limb of the cartilage and wrapping around the deep end of the cartilage (Stibbe, 1928). The Harderian gland is absent in man but present in those animals which have a well developed third eyelid. The gland of the rabbit is large, complex and surrounded by a delicate capsule and a venous sinus and lies at the base of the third eyelid (Davis, 1929). Recently Prince *et al.* (1960) reported its presence in cattle, pigs, and rabbits and its absence in dogs, cats, sheep, and goats. The pig is the only domestic animal which contains the Harderian gland as a separate organ (Trautmann and Fiebiger, 1957). The Harderian gland of the ox is confluent with the nictitating gland and both are surrounded by a common sheath (Prince *et al.*, 1960).

Histology - The conjunctiva of the third eyelid of domestic animals contains scattered lymphocytes and lymph nodules (Prince *et al.*, 1960; Trautmann and Fiebiger, 1957) and many goblet cells in man (Wolff, 1955). The free margin of the third eyelid contains pigment cells and elastic tissue in domestic animals and man (Prince *et al.*, 1960; Wolff, 1955). The presence of smooth muscle in the third eyelid of vertebrates was denied by Ihle *et al.* (1927) but was observed by Lawrentjew and Borowskaja (1936), Groyer (1903) and Stibbe (1928) in various mammals. Acheson (1938) observed two sheets of well developed smooth muscle in the nictitating membrane

of cats. The base of the human plica semilunaris contains some smooth muscle fibers and fat (Wolff, 1955).

The cartilage of the third eyelid is generally hyaline in domestic animals except in the horse, cat and pig in which it is elastic. It is lacking in birds (Trautmann and Fiebiger, 1957). The cartilage is incased by collagenous tissue which sends septa into the surrounding nictitans gland (Price et al., 1960).

The superficial gland of the third eyelid (nictitating gland) which surrounds the cartilage is serous in the horse and cat, mixed in the ox, sheep and dog and mucous in the pig (Trautmann and Fiebiger, 1957). Histologic structure of the nictitating gland of domestic animals resembles the lacrimal gland. The gland is covered by a connective tissue sheath which invades the parenchyma by many septa containing ducts, blood vessels, nerves and in some animals fat cells. The acini are lined by a single layer of pyramidal cells and the ducts by one or two layers of columnar cells (Prince et al., 1960). The nictitans gland of the rabbit has several ducts which pierce the cartilage and open on the inner surface of the membrane. The gland is made up of small acini, the cells of which contain numerous secretion grandules (Davis, 1929).

The histology of the Harderian gland was first described by Loewenthal (1892) in the guinea pig, mouse, rat, pig, sheep, calf and horse. The microscopic structure of the gland has been studied in pigs, horses and mules by Aureli (1957) and Aureli and Tanzii (1959); in rabbits by Björkman et al. (1960), Davis (1929) and Schnier (1950); in rats and mice by Chiquoine (1958), in birds and domestic animals by Stibbe (1928), and in mammals by Wendt (1877 cited by Wolff, 1955). According to these authors the Harderian gland is a tubuloalveolar gland. Harderian glands sometimes have two lobes, one white, the other pink which differ in histologic structure. Large fat globules are

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seen in the pink lobe whereas only small fat droplets are present in the white lobe. The ducts open on the bulbar surface of the nictitating membrane. The structure of the Harderian gland is sometimes reminiscent of a sebaceous gland and holocrine in nature (Aureli and Carelli, 1956). According to Cohn (1955), Davis (1929) and Paule (1958) it is an apocrine gland. Myoepithelial cells are also found in this gland (Chiquoine, 1958).

Histochemistry - On histochemical examination, Aureli and Tanzii (1959) reported that the glands of the third eyelid of the horse and mule contain mycopolysaccharides, lipids, nucleic acid and enzymes. They considered the gland seromucous in type. Materazzi and Travaglini (1961), from their research on the orbital glands of the various mammals, reported that the secretion of the third eyelid of sheep contains a PAS positive substance. Histochemical studies of the Harderian gland were done in the pig by Aureli (1957); in mice and rats by Cohn (1955), Collins (1957) and Grafflin (1942); in rodents by Derrien and Turchini (1924); in amphibia, reptiles and birds by Paule (1958); and in rabbits by Schneir (1950). According to these authors and Prince *et al.* (1960) five types of Harderian glands have been recognized in the vertebrates, four of which occur in mammals: lipid secreting, mucous, seromucoid and mixed. Most mammals have lipid secreting Harderian glands. The presence of phospholipids, triglycerides, cholesterol, alkaline and acid phosphatases, lipase, proteins, iron and glycogen in the Harderian gland have been observed in the albino mouse by Cohn (1955) and in rabbits by Schneir (1950). The yellow-brown pigment (porphyrin) was observed in the Harderian glands of mice by Collins (1957) and of rabbits by Schneir (1950).

PERIORBITA (ORBITAL PERIOSTEUM)

The periorbita or orbital periosteum lines the bony wall of the orbit (Wolff, 1955). It is a conical fibrous membrane which encloses

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the eyeball and its associated structures (Sisson and Grossman, 1953) with the exception of the lacrimal gland which lies outside the cone in a special compartment formed by the periorbita (Prince et al., 1960). The apex of the periorbita is attached at the orbital group of foramina and its base is attached to the orbital margin and continued as the fibrous layers of the lid. It is thin medially where it comes in contact with the bony wall of the orbit and thick laterally where it is reinforced by the elastic fibers which are attached to the pterygoid crest (Sisson and Grossman, 1953). It consists of two layers: outer, containing loose collagenous and fine elastic fibers and spindle shaped connective tissue cells, and inner, containing dense connective tissue and blood vessels (Prince et al., 1960).

ORBITAL FASCIA

The bulbar fascia (Tenon's capsule) is a thin fibrous membrane which covers the eyeball from the corneo-scleral junction to the optic nerve (Wolff, 1955) and separates the eyeball from the orbital fat (Bedrossian, 1958). Its inner surface is attached to the sclera by fine trabeculae and the outer surface is in contact with the orbital fat. Tenon's capsule is pierced anteriorly by the tendons of the extrinsic ocular muscles and posteriorly by the optic nerve and ciliary arteries and nerves. The lower part of Tenon's capsule which is thickened to form a sling or hammock for the eyeball is known as the ligament of Lockwood (Wolff, 1955). This ligament is attached laterally and medially to the wall of the orbit by condensed fibrous tissue called the check ligaments. Muscular fasciae (muscle sheaths) are reflections of Tenon's capsule over the ocular muscles. These muscle sheaths also extend from one muscle to others forming the intermuscular membrane (Bedrossian, 1958).

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EXTRINSIC OCULAR MUSCLES

A historical survey of extrinsic ocular muscle was made by Cole (1944). According to him eye muscles including the retractor oculi (choanoid) and the cutaneous muscles of the eyelids were carefully explored by Galen. Vesalius found the retractor oculi muscle originally in the dog but described it in man as he was not aware that it is absent in man and higher mammals. Casserius was the first to demonstrate that the retractor oculi muscle does not occur in man. This muscle reaches its highest development in some ruminants where it forms a continuous cone surrounding the optic nerve as it enters the orbit. The retractor oculi has received a variety of names such as posterior rectus, suspensor colli and choanoid.

Gross - The orbital muscles are poorly developed in invertebrates but well developed in vertebrates. In fishes, amphibia, reptiles, and birds these muscles are less mobile (Wolff, 1955). The gross anatomy of the ocular muscles has been described in every text book of anatomy both animal and man. According to Prince et al.(1960) and Sisson and Grossman (1953), extrinsic ocular muscles in domestic animals are four recti, two oblique and one retractor. In the rabbit, Davis (1929) described ten extrinsic ocular muscles namely the orbicularis, levator palpebrae superioris, depressor palpebrae inferioris, four recti, two oblique and retractor bulbi. In addition to six extrinsic skeletal muscles in the human orbit, Wolff (1955) described four groups of smooth (capsulo-palpebral) muscles namely, the superior, inferior, superolateral and superomedial palpebral. The retractor oculi is absent in birds and serpents (Wolff, 1955). The branches of the external ophthalmic and malaris arteries supply blood to these muscles (Prince and Ruskell, 1960). These muscles are innervated as follows: the superior, inferior and medial recti and inferior oblique by the oculomotor, the lateral rectus and retractor oculi

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Histology - As these extrinsic skeletal ocular muscles are derived from the branchial arches, they are more highly differentiated than other skeletal muscles of the body (Wolff, 1955). Since these muscles have the smallest fibers of all voluntary muscles and their striations are poorly developed, they appear intermediate between skeletal and smooth muscles (Bedrossian, 1958). Many nerve and elastic fibers are seen between the muscle bundles. In the past, there was a controversy about the existence of sensory muscle spindles in these muscles but through recent investigations it is now well established that they exist in man as well as in animals. Daniel (1946) and Cooper and Daniel (1949) reported muscle spindles in the human extrinsic muscles of the eye. According to Prince et al. (1960), Wolter (1954) observed six different types of sensory nerve endings in the human extrinsic ocular muscles. Fukuda (1958) found five distinct kinds of nerve endings in the extrinsic ocular muscles of the rabbit and traced them to the oculomotor nerve and cervical sympathetic ganglion. According to him, the muscle spindles were absent, but definite sensory nerve endings of thin medullated nerve fibers were present. In these muscles of dogs according to Fukuda (1958), Kure, Shiba and Okinaka (1931) described four types of nerve endings derived from pyramidal (motor), extrapyramidal, sympathetic and parasympathetic nerves. Sensory nerves were not reported by them. The existence of the muscle spindles in the extrinsic ocular muscles of sheep and goats was confirmed by Cilimbaris (1910). Winckler (1936, 1937) reported the presence of proprioceptive nerves in these muscles of sheep and goats. Whitteridge (1955) found a separate afferent nerve supply to these muscles in goats.

THE LACRIMAL APPARATUS

Lacrimal Gland

Gross - The lacrimal gland is a modified cutaneous gland developed from the conjunctival sac (Wolff, 1955). Fishes have no lacrimal gland. The change of the environment from aquatic to terrestrial, necessitated the development of a secretory apparatus in connection with the eyes. Thus in the urodeles, a series of glands develop from the conjunctiva of the lower lid. In anurans and reptiles they become more developed and divided into the lateral and medial groups, the lateral being the lacrimal, and the medial the Harderian glands. In mammals, the process of evolution continues until the gland comes to lie beneath the upper lid (Kingsley, 1917; Prince 1956). The development of the lacrimal gland of the rabbit, guinea pig, pig, sheep and man was studied by Falchi (1905). Gross anatomy of the gland was described by Ellenberger and Baum (1943). Prince et al. (1960) and Sisson and Grossman (1953) in various domestic animals. The gland is situated at the lateral angle in birds, slightly in the upper but mostly in the lower lid in rabbits (Davis, 1929; Wolff, 1955) below the supraorbital process in the horse and beneath the orbital ligament in the dog (Smythe, 1956). The gland of the ox is better developed and is divided into two lobes, the upper and lower (Sisson and Grossman, 1953). The gland is innervated by the lacrimal, sympathetic and parasympathetic nerves. Parasympathetic fibers in cats reach the gland through the lacrimal nerve (Botelho, 1964). The gland of the ox is supplied by the lacrimal artery which is a branch of the ophthalmic artery (Sundwall, 1916).

Histology - The lacrimal gland is a tubuloalveolar serous gland in the cat, horse, ox, pig, and rabbit, mixed in dogs and sheep and compound tubuloalveolar mucous in the goat (Prince et al., 1960).

The goat's lacrimal gland is described by Trautmann and Fiebiger (1957) as a mixed tubuloalveolar gland. Various other authors such as Prince *et al.* (1960), Wolff (1955) and according to Sundwall (1916), Boll (1868), Ellenberger and Gunther (1888), Flemming (1888), and Leydig (1857) have described the microscopic structures of the lacrimal gland in the domestic animals and man. In the lacrimal gland of the ox numerous plasma cells are noted in both the interlobular and intralobular tissue, especially around the ducts and between the acini (Sundwall, 1916). The presence of plasma cells has been reported in the human lacrimal gland by Hannes (1911). The blood supply and lymphatics of the gland have been studied by Prince and Ruskell (1960) and Puglisi-Allegra (1904) in the domestic animals. Dogiel (1893) using methylene-blue and Golgi's methods observed a peritubular and intercellular network of nerve fibers in the lacrimal gland of the guinea pig and rabbit. Puglisi-Allegra (1903) used Golgi's method and vital staining with methylene blue and observed peritubular, pericellular and intracellular fibers, and sympathetic ganglia cells situated along the course of the sympathetic fibers in the lacrimal gland of the pig. Hisada and Botelho (1963) studied the functional innervation of the lacrimal gland in the cat. Kato (1958) found medullated and non-medullated nerve fibers and nerve endings in the human lacrimal gland.

Biochemistry and histochemistry - In all domestic mammals the secretory cells of the lacrimal gland contain fat droplets (Trautmann and Fiebiger, 1957). A histochemical study of the lacrimal gland in dogs and cats was done by Materazzi and Travaglini (1961). By histochemical methods Spicer and Duvence (1964) observed mucopolysaccharides in the exorbital lacrimal glands of the hamster, mouse and rat and reported the abundant presence of ribonucleic acids in the lacrimal gland of the hamster. According to Krause (1934) Seki (1926)

noted cholesterol in the tears of rabbits. According to Fleming and Allison (1925) the protein in the tears of the horse, cow, sheep, turkey and man is species specific. Goldsworthy and Florey (1930) reported that the tears of dogs and goats possess bacteriolytic properties. Fleming and Allison (1922) discovered a bacteriolytic substance (lysozyme) in the tears and tissues of all animals.

Lacrimal Excretory Ducts

Gross - The number of excretory ducts are 12 to 16 in the horse, 6 to 8 large and several small ones in the ox and 4 to 5 in the pig (Prince et al., 1960; Sisson and Grossman, 1953). The ducts in dogs are too small to distinguish grossly but open into the superior fornix. In the horse they open on the conjunctival surface of the upper lid near the lateral canthus (Smythe, 1956). In cattle the ducts are well developed and open in a line on the lateral half of the superior palpebral conjunctiva about 1.5 cm behind the lid margin (Sundwall, 1916). These ducts in the camel open together in a wide tunnel-like recess in a conjunctival fold just above the posterior (lateral) canthus (Tayeb, 1962). The excretory ducts in primates mostly open in the upper lid but some always open in the lower one also. In the tortoise, bird, rodent, and lamb, these ducts unite to form a single duct which opens in the lower lid (Wolff, 1955).

Histology - In domestic animals the smaller excretory ducts are lined with a single layer of cuboidal cells; the larger ones have two layers. In the pig the epithelium becomes high columnar (Trautmann and Fiebiger, 1957). In sheep the intertubular ducts are lined by a single layer of cuboidal cells surrounded by a heavy, coarse connective tissue sheath (Prince et al., 1960). The excretory ducts of cattle are lined with stratified cuboidal epithelium containing many goblet cells (Sundwall, 1916).

Puncta lacrimalia

In domestic animals the Puncta lacrimalia, the entrances of the canaliculi, are generally two in number, situated one on each lid margin near the medial canthus. The lower one is sometimes absent in the dog and always absent in the pig. The rabbit has only one punctum situated on the inner surface of the lower lid (Prince et al., 1960). Each punctum lacrimale of the camel is protected by two papillae, one in front and the other behind (Tayeb, 1962). In birds, both puncta enter a wide lacrimal canal which opens into the nasal cavity immediately above the inner nares (Nicolas, 1924). The opening is lined by the continuation of the conjunctiva of the lid margin and is surrounded by collagenous tissue and a few fibers from the orbicularis oculi muscle (Wolff, 1955).

Lacrimal Canaliculi

The canaliculi (lacrimal ducts) in domestic animals are two, one in each lid, except there is only one lacrimal duct in the pig and ewe (Wolff, 1955), the rabbit and bat (Minamikawa, 1958) and sometimes the dog (Prince et al., 1960). The ducts are entirely absent in the seal, hippopotamus and elephant (Wolff, 1955). The wall of the upper canaliculus of swine contains cartilage (Trautmann and Fiebiger, 1957). The ducts are lined by stratified squamous epithelium (Minamikawa, 1958).

Lacrimal Sac

The lacrimal sac, the dilated origin of the nasolacrimal duct is situated in the lacrimal fossa which is the funnel like orbital end of the osseous lacrimal canal (Sisson and Grossman, 1953). The sac receives its blood supply through the branch of the malaris artery (Prince and Ruskell, 1960). In man, the sac is innervated by the

infra-trochlear and anterior superior alveolar nerve (Wolff, 1955). The sac of domestic animals is lined by stratified epithelium which may be columnar or transitional in the pig. The tunica propria in the horse contains lymphocytes and sometimes lymph nodules (Trautmann and Fiebiger, 1957).

Nasolacrimal Duct

The nasolacrimal duct originates from the lacrimal sac, passes anteriorly first through an osseous canal, then in an osseous groove and finally opens near the nostril on the lateral wall of the nasal cavity in the ox, on the skin of the floor of the nostril in the horse and on the lateral wall of the nostril in the dog (Sisson and Grossman, 1953). The nasolacrimal canal is curved, 25-30 cm long and 4-5 mm wide in the horse, short and almost straight in the ox and pig. There is no valve near the lacrimal sac in the domestic animals as seen in man. Sometimes its nasal opening is represented by two or several openings in the horse (Nicolas, 1924). The nasolacrimal duct usually opens into the nasal cavity, but in some burrowing snakes it opens into the mouth which suggests that tears developed not only to moisten the eye but also to moisten the nose and mouth. In lizards and in most snakes the duct opens into the organ of Jacobson (Botelho, 1964). Minamikawa (1958), after studying the comparative anatomy of the ductus nasolacrimalis in the rabbit, dog, cat, mouse, guinea pig, bat and mole reported that the duct was lined with stratified squamous epithelium and was surrounded by a venous plexus. He also observed the absence of smooth muscle in the wall of the duct. According to Trautmann and Fiebiger (1957) the duct of the horse contains mucous glands and lymph nodules in the subepithelial layer.



MATERIALS AND METHODS

Source of Animals

The animals used for this investigation were obtained from the Dairy, Physiology (endocrine research unit) and Surgery and Medicine Departments at Michigan State University. All animals except one were slaughtered for meat purposes and were clinically healthy. One animal which was used for urethrotomy was electrocuted in the postmortem room. Specimens were collected within 10 to 20 minutes after slaughter. For histologic study, the eye specimens were obtained from 15 different areas of the eye adnexa of 8 male sheep, 2 weeks to 5 months old; 8 female sheep, 3 months to 4 years old and 4 male goats, 5 days to 5 months old. In addition, 4 heads of female sheep 3 to 4 years old were used for gross anatomy. For histochemical study, frozen specimens from 2 sheep, 2 months and 2 years old and 2 goats, 5 days old were used. Paraffin processed specimens from all animals were used for histologic study.

Technique

For gross anatomy 10% formalin fixed and latex injected specimens were dissected. For the study of the course of the lacrimal drainage passage and blood vessels of the orbit a radiopaque substance ("Micropaque"*) was mixed with water and injected into them and radiographs were taken. For the detailed study of the blood vessels of the eyelids, muscles and lacrimal glands, India ink was injected into the carotid artery. The eyelids, lacrimal glands and extrinsic ocular

*Picker X-ray Corporation, 25 South Broadway, White Plains, New York.

muscles were removed from the orbit and passed through 1% formic acid for 2 hours, 50% alcohol for 1 hour, 70% alcohol for 1 hour, acetone two changes first for 72 hours and then for 24 hours, acetone methyl benzoate 50:50 mixture for 24 hours and finally into methyl benzoate until the specimens became transparent and blood vessels were seen clearly. For the dissection of the lacrimal excretory ducts and counting of cilia, a dissection microscope and magnifying lens were employed.

The specimens for histologic study were removed within 15 to 20 minutes after slaughtering the animals and were preserved in 10% neutral formalin. After a week, the specimens were trimmed to suitable size and stored in 10% neutral formalin solution. These specimens were dehydrated by the dioxane method (Bucher and Blackely, 1936). Most of the tissues were infiltrated with paraffin and a few with paraplast 5 to 8 changes at 15 minutes each. They were alternately kept in vacuum and under 15 pounds of pressure. Sections were cut at 6 to 8 microns. They were stained with (1) Harris hematoxylin and eosin (Malewitz and Smith modification, 1955) for general study, (2) Weigert and Van Geison's stain (French, 1929) for elastic tissue, (3) Mallory's triple stain (Crossmon modification, 1937) for connective tissue, (4) Gomori's reticular stain (Gridley, 1957) for reticular tissue, and (5) Modified Bielschowsky-Gros silver stain for nerve endings (Cauna, 1959).

For histochemical study, tissues were taken immediately after slaughter of the animals and frozen with dry ice. Frozen and paraffin processed tissues were cut at 6 to 8 microns. Paraffin sections were stained with (1) Alcian Blue and Nuclear Fast Red for mucopolysaccharides and mucoproteins, (2) Toluidin Blue (1:1000) for mast cells and mucin (Gridley, 1957), and tested with (3) Periodic acid Schiff (PAS) reagent for glycogen, and mucopolysaccharides. Frozen

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sections were treated with (4) Sudan Black for total fat (5) Nile Blue Sulfate for triglyceride (Gridley, 1957) and (6) Naphthal As-BI and phosphoric acid for acid phosphatase and Naphthal As-Mx and phosphoric acid for alkaline phosphatase (Burstone, 1961).

Measurements

The thickness of the whole lid and lacrimal gland was measured with a vernier slide calipers. The thickness of the epidermis, dermis, hair, the connective tissue fibers, sebaceous and sweat glands and ducts of various glands were measured in microns with an ocular micrometer.

RESULTS AND DISCUSSION

EYEBROWS

Gross - The eyebrows which are characteristic features of primates are not distinctly demarcated in sheep. The skin over the edge of the supraorbital process is thick and the supercilia are represented by some long hairs toward the medial canthus (Plate I). The majority of the long hairs are sensory hairs but a few of them are supercilia. Since sheep eyebrows contain dense wool hairs in this area an abundance of supercilia as in primates is not required. The blood and nerve supply is similar to that of the superior lid.

Histology - The epithelium, as in the general skin, is composed of stratified squamous epithelium having 4-6 layers of cells. The stratum basalis is composed of cuboidal cells which are not distinctly arranged in a row. The corium is thicker than in the adjacent skin and contains dense collagenous, fine elastic and some striated muscle fibers. Three kinds of hairs are found in this area: wool hairs, supercilia and sensory hairs. The sebaceous glands are better developed than in the eyelids and the sweat glands are saccular. The fibers of the frontalis muscle which run perpendicular to the upper lid join the bands of the orbicularis oculi muscle and the skin (Plate IX).

The eyebrows in goats are better marked than in sheep because wool hairs are lacking in this animal. Supercilia and sensory hairs are present (Plate X).

EYELIDS (PALPEBRAE)

Gross - Both eyelids of sheep are movable folds of the skin which protect the eye from external injury by foreign bodies. They clean and

moisten the cornea, spread the tears uniformly, remove excessive fluid and regulate the amount of light to the eye. The palpebrae are united on either side by corresponding lateral and medial commissures. The medial commissure is unpigmented and marked by a groove which extends from the palpebral fissure to a cutaneous pouch known as the lacrimal or infraorbital pouch (Plate I). The pouch is about 2.5 cm. long, 1 cm. wide and 1.5 cm. deep and is covered by generally unpigmented soft greasy skin and a few fine hairs. It resembles the skin of the external ear canal. The lateral commissure joins both lids and is pigmented. The palpebral fissure (Rima palpebrum) is elliptical in shape but wider towards the medial canthus and is about 26 mm. long and 12 mm. wide (Plate I). The lateral canthus (angle) is wide and rounded while the medial canthus is narrow and joined to the lacrimal pouch by a groove (Plate I). The lacrimal lake (Lacus lacrimalis) is present as a small depression which contains at its medial aspect a small rounded pigmented eminence known as the lacrimal caruncle (Caruncula lacrimalis). Each lid consists of two surfaces: the external and internal, and two borders: the attached and free. The external or cutaneous surface is convex and, when the lids are opened, presents a shallow groove preceded by a fold near the base of the lid. This feature is especially prominent in the upper lid. The internal or palpebral surface is smooth and concave to adapt to the eyeball. The attached border is convex and joined to the rim of the bony orbit. The free border is concave and forms the boundary of the palpebral fissure. The free border is rounded in cross section and its two margins, Limbus palpebralis anterior and posterior are not demarcated in sheep as in the horse. The upper eyelid is larger and thicker than the lower one which is opposite from cattle according to the observations of the author (Sinha, 1964). The average thickness is 2 mm

at the margin and 1.3 mm at the post-tarsal region of the upper lid while correspondingly 1.7 mm and 1.2 mm in the lower eyelid.

Grossly each lid is composed of the skin, subcutis, muscular layer, tarso-fascial layer, and palpebral conjunctiva.

The skin is attached tightly to the underlying structures at the free border of the lids and loosely elsewhere, it is more movable on the upper lid than on the lower one. Fine, short wool hairs and a few scattered tactile hairs are found on both eyelids. The fine long hairs upon the medial aspect of the upper lid are not all sinus hairs as stated by Prince et al. (1960). A few of them are supercilia. The skin at the free margin is smooth and generally pigmented. The number, length and distribution of eyelashes (cilia) are variable in both lids (Plate I). In the upper lid there are about 130 cilia arranged in 3-4 rows. They are longer in the middle of the lid and are absent at the medial canthus. In the lower lid there are about 95 cilia. They are thinner and shorter than those of the upper lid and are more concentrated at the center. The subcutis is intermingled with the muscles and not distinctly separable from them.

The palpebral muscles in sheep are the orbicularis oculi, levator palpebrae superioris, frontalis and malaris. The orbicularis oculi is a thin, elliptical muscle encircling the palpebral fissure and acting as its sphincter. It is attached laterally and medially by corresponding palpebral ligaments. The Pars lacrimalis (Horner's muscle) which is a slip off the orbicularis oculi muscle is a very thin slender band of muscle attached to the notch formed by the orbital margins of the lacrimal and frontal bones and upper posterior aspect of the lacrimal sac. The levator palpebrae superioris is a slender, thin muscle arising from the pterygoid crest and inserting as a thin tendon on the upper lid. It elevates the upper lid. The frontalis is a thin cutaneous muscle covering the frontal bone. Its fibers are attached

on the superior border of the orbicularis oculi in the upper lid. It assists in raising the upper lid. The malaris muscle is a thin, small, fan-shaped muscle arising from the fascia over the buccinator muscle and inserting into the medial palpebral ligament and adjacent structures. It depresses the lower lid.

The tarso-fascial layer consists of the tarsus anteriorly and palpebral fascia (orbital septum) posteriorly. The tarsus of sheep is a poorly developed, thin covering of the tarsal glands, attached laterally and medially by corresponding thin palpebral ligaments. Its convex border is continuous with the palpebral fascia which is a thin fibrous band forming the core of the lid and attaching to the margin of the orbit. The tarsal (Meibomian) glands, enclosed by the tarsus, are arranged parallel to each other and vertical to the lid margins. They are faintly visible through the conjunctiva. The palpebral conjunctiva is thin, smooth and pinkish in color and forms the mucous membrane of the inner surface of the lids.

The blood supply to the lids comes from the superior and inferior medial palpebral branches of the malar artery and the superior lateral palpebral and lateral commissural branches of the superficial temporal artery (Plates VI and VII). The blood is drained by corresponding veins. The general pattern of distribution of the blood vessels is in agreement with the description given by Prince and Ruskell (1960). The lids are innervated by the branches of the ophthalmic and maxillary divisions of the trigeminal, facial and oculomotor nerves. The facial nerve supplies the orbicularis oculi and malaris muscles, while the oculomotor supplies the levator palpebrae superioris muscles. With the exception of the absence of a lacrimal pouch the gross anatomy of the eyelid of the goat is generally similar to that of sheep. The eyelids of goats are slightly longer than those of sheep.

Histology - Microscopically the lids are composed of eight layers: the skin, subcutis, striated muscle, submuscularis, tarso-fascia, smooth muscle, subconjunctiva and conjunctiva.

The thickness of the epidermis varies according to the area, thicker at the free margin and thinner towards the base. The epidermis is composed of stratified squamous epithelium consisting of 7-8 layers of cells at the free margin and 3-4 on the remainder. Of the five layers of the epidermis the stratum lucidum is absent. The stratum granulosum generally consists of a single layer of cells separated widely on the cutaneous surface and placed closely at the free margin of the lid. The stratum basalis contains cuboidal cells which are not arranged in a distinct row. The rete pegs and abundant pigment granules are present in the epidermis at the free margin of the lid (Plate XIX). Some clear cells (melanocytes) are also present in the stratum basalis. The dermis and subcutis are not distinctly separated. The dermis is composed of dense collagenous and fine reticular and elastic fibers and contains some skeletal and a few smooth muscle fibers. The dermal papillae, present at the free margin of the lid, are of various sizes. Mast cells are present in the papillary and reticular layers particularly around the blood vessels. Three kinds of hairs are found on the palpebrae: eyelashes, tactile hairs and wool hairs. The eyelashes, located at the free margin of the lids, are thick, pigmented and deeply rooted. They are provided with modified well-developed sebaceous and sweat glands (Plate XIII). Tactile (sensory, sinus) hairs are surrounded by thick connective tissue sheaths which enclose a vascular sinus. The highly developed, multilobulated encircling sebaceous glands pierce the inner and outer epithelial sheaths (Plate XVII). Wool hairs are fine, crimped, of various sizes, devoid of medulla and evenly distributed. They are long and dense at the base and short, fine and scarce towards the ciliary margin of the eyelid.

They are not as deeply rooted as cilia and sensory hairs. They are curved near the bulb and their follicles are irregular in shape. A few secondary wool hairs were also seen. The follicular folds are not distinct in wool hairs of the lids but a few were noticed in large coarse hairs and cilia. Follicular folds are present in the inner epithelial sheath near the opening of the sebaceous gland. Near the ciliary follicular folds the external epithelial root sheath is surrounded by a nerve plexus and contains highly developed dense columnar cells (Plate XIII). The palpebral sebaceous and sweat glands vary in shape and size according to the type of hairs with which they associate. The sebaceous glands associated with wool hairs are smaller than those with ciliary and sensory hairs. Zeis glands are modified, large sebaceous glands associated with the cilia. Generally two Zeis glands are supplied with each cilium and each gland contains 2-3 lobules (Plate XIII). They are simple branched alveolar glands having a body and a smaller duct. Each alveolus is composed of glandular cells resting on a basement membrane. The duct is short, opens in the hair follicle and is lined by stratified squamous epithelium. The lacrimal (infraorbital) pouch glands are large modified multilobulated sebaceous glands (Plates XVIII and LIII). The sweat gland is a saccular gland having a bag-like body and a narrow, long excretory duct lined by simple low cuboidal or flattened cells. It is always associated with a hair follicle. The sweat glands associated with cilia are highly modified, spiral, simple tubular gland and are known as glands of Moll. Each gland consists of the body (secretory part) and the duct (excretory part). The gland is composed of three layers: the epithelium, myoepithelium and basement membrane. The epithelium is simple columnar in the body, cuboidal in the lower part and stratified squamous at the mouth of the duct. In some of the glands the apical cytoplasm protrudes into the lumen in various forms and in others, the lumens contain the broken

apices of the cells. The myoepithelial cells are mostly parallel to the axis of the gland (Plate XV). The observation of well-developed glands of Zeis and Moll associated with cilia in sheep are in agreement with reports of Sinha (1964) in cattle and Trautmann and Fiebiger (1957) in domestic animals, but opposite of man described by Wolff (1955). The subcutis of the eyelid is composed of loose areolar tissue and contains no fat in the margin and body but does contain some fat cells at the base of the lids (Plate XIV).

The striated muscle layer is composed mainly of the fibers of the orbicularis oculi. The fasciculi of the orbicularis oculi are more concentrated towards the base and free edge and less concentrated in the middle of the lid. The muscle of Riolan, composed of the muscle fibers of the orbicularis oculi at the free lid margin, is distinct and surrounds the cilia, glands of Moll and ducts of the Meibomian glands (Plate XV).

The submuscularis which resembles the subcutis in structure, is composed of areolar tissue and the aponeurosis of the levator palpebrae superioris in the upper lid. It is fused with the tarsus below. It contains large nerve trunks and blood vessels.

The tarsus in sheep is a poorly developed fibrous membrane dorsal to the tarsal gland. It is composed of mostly dense collagenous and a few fine elastic fibers. It fuses with the thin capsule of the tarsal gland. The palpebral fascia (orbital septum) connects the tarsus to the thickened periorbita at the orbital bony margin (Arcus marginale) and is pierced by blood vessels, nerves and tendons of the levator palpebrae superioris in the upper lid (Plate XXXVII). The tarsal (Meibomian) glands are tubuloalveolar, well-developed, arranged parallel, modified sebaceous glands independent of any hair follicle (Plate XI). They are larger and more numerous in the upper than in the lower lid. They are longer at the middle, shorter towards the periphery and absent near

the canthi. They open inside the lid margins in a line. Each gland consists of a central duct surrounded by a number of alveoli which open into it. The alveoli are like sacs filled with solid glandular cells. The sac wall (basement membrane) is composed of homogeneous material inside and reticular fibers outside. The peripheral glandular cells are small and cuboidal with large oval nuclei, while the central ones are large and polyhedral. At the mouth of the alveoli, there are many degenerated, vacuolated cells, and a few containing fat droplets (Plates XI and XIX). The main duct is lined with stratified squamous epithelium having 5-6 layers of cells near the mouth and 3-4 layers in the body of the gland (Plate XIX). The cells at the mouth show keratinization which gradually decreases inwardly. In most of the Meibomian glands pigment granules are observed in some of the alveoli, in the lumen, and in the peripheral cells lining the main duct.

The smooth muscle band known as the muscle of Müller, forms a distinct layer in the eyelid of the sheep. The muscle is better developed towards the base of the eyelid and continues forward by a lamina formed by well-developed elastic and collagenous fibers which end at the tarsus (Plate XVI). The muscle of Müller arises from the medial surface of the levator palpebrae superioris in the upper lid and the fibrous sheath of the inferior rectus in the lower lid. The superior muscle of Müller, near the fornix, gives a slip to the base of the membrana nictitans and then passes into the superior eyelid. The origin and distribution of muscle fibers of Müller are in agreement with the description given by Nicolas (1924) and Prince et al. (1960) in domestic animals and by Wolff (1955) in man.

The subconjunctiva and tunica propria are continuous and composed of dense collagenous tissue. The tunica propria is nearly absent at the free edge, thin at the tarsus and contains fat cells near the base.

The microscopic structure of the eyelids of goats is similar to that of sheep except that the wool hairs are absent in goats and the free edge is steep and contains a distinct posterior margin. The sweat glands and glands of Moll are better developed. Frontalis muscle fibers join orbicularis oculi muscle like that of sheep (Plate XII).

Histochemistry - With Sudan black, frozen sections of the sebaceous glands and its modification, namely, glands of Zeis and Meibom become black colored and show intense sudanophilia. The glandular cells are generally filled with sudanophilic droplets which obliterate cellular details. The aggregated droplets in the form of globules and clumps of sudanophilic material are visible in the lumen and adjacent structures near the mouth of the gland. The cells of the duct are less sudanophilic. Nile blue sulfate exposes the saturated or unsaturated triglyceride in the form of red droplets in the glandular cells and in the lumen of the alveoli and excretory ducts. In paraffin sections, with periodic acid Schiff reagent, the capsule and cell membrane of the sebaceous gland and its modifications are PAS positive. In the lumen of the Meibomian gland, the cell membrane of vacuolated cells are obvious. With alcian blue the nuclei stain pink and the cytoplasm contains vacuolated unstained globules surrounded by bluish stained cytoplasm. The cytoplasm of the cells stained with the toluidin blue gives a weak reaction. These observations suggest that the sebaceous gland and its modifications, glands of Meibom and Zeis, are holocrine and lipid secreting glands. The sweat gland and its modification, the gland of Moll, react weakly with Sudan black. Black stained filamentous structures resembling mitochondria are seen in the cytoplasm. The gland reacts very weakly with Nile blue sulfate. The alkaline phosphatase activity is stronger in the myoepithelial cells than in the glandular epithelium, while with acid phosphatase, nuclei of both cells react strongly. With the periodic acid Schiff reagent some

fine PAS positive granules are found in the supranuclear cytoplasm of the gland of Moll but cytoplasm and luminal contents are weakly PAS positive. With alcian blue, nuclei stain pink and the cytoplasm light blue. These histochemical observations along with the microscopic picture indicate that the gland is apocrine and is both a mucopolysaccharide and a lipid secreting gland. This observation agrees with the histochemical findings of the sweat gland of cattle by Ato (1961a, b). The dermo-epidermal junction contains a PAS positive network of fine fibers. Similar reactions are observed in the goat sections.

CONJUNCTIVA

Gross - The conjunctiva of sheep is a thin, transparent, protective mucous membrane lining the eyelids and reflecting over the front of the eyeball. The angle of reflection, the fornix conjunctivae (Plates XXIII, XXIV and XXV), is an elliptical cul-de-sac which is interrupted at the medial canthus by the caruncle and membrana nictitans. The potential space between the bulbar and palpebral conjunctivae known as the conjunctival sac opens at the palpebral fissure (Plate III). According to the situation the conjunctiva is divided into 5 parts: the palpebral, fornix, bulbar, nictitating and caruncular conjunctivae.

The palpebral conjunctiva lines the lid and is further subdivided into marginal, tarsal and post-tarsal regions. The marginal conjunctiva is a transition zone between the skin and the conjunctiva. It is generally pigmented and tightly attached to the free lid margin. It also lines the punctum lacrimale. The tarsal conjunctiva is thin, closely attached to the tarsus and sufficiently transparent that tarsal glands are faintly visible through it. The post-tarsal conjunctiva lies

between the tarsal and fornix conjunctivae. It is loosely attached to the underlying structures and hence is easily folded.

The fornix conjunctiva joins the eyelids with the eyeball and is highly vascular. According to position, it is also further subdivided into the superior, inferior, lateral and medial zones. It is loosely attached to the subconjunctival tissue and thus always presents folds of various shapes and sizes (Plate XXIV). The superior fornix gives attachment to the fibrous sheath of the levator palpebrae superioris and superior rectus muscles.

The bulbar conjunctiva is thin and transparent and lines the visible part of the sclera (white of the eye) and cornea and is subdivided into the scleral and corneal zones. The scleral conjunctiva extends from the fornix to the corneal limbus and is loosely attached to the underlying structures and thus allows easy movement of the eyeball. It presents some folds near the fornix (Plate XXXI). The corneal conjunctiva is completely fused with the substantia propria of the cornea and forms the corneal epithelium (Plate XXVI). It is non-vascular and transparent.

Grossly the conjunctiva of the goat resembles that of sheep. The palpebral conjunctiva is thinner than in sheep and more tightly attached to the lids causing the Meibomian glands to be more prominent.

Histology - The conjunctiva, like other mucous membranes, is composed of two layers: the epithelium and tunica propria. The epithelium is very irregular. At some places it appears stratified squamous, at others stratified cuboidal to columnar and at certain spots even transitional. The substantia propria is equally variable.

The palpebral conjunctiva at the margin of the lid is composed of stratified squamous epithelium having 8-12 layers of cells. The surface cells are keratinized. The keratinization ends near the muco-cutaneous junction which is distinctly marked behind the opening of the Meibomian

glands. Behind the junction, nuclei which are parallel to the surface are seen in the superficial cells (Plate XIX). The intermediate cells are polygonal with large oval nuclei. The cuboidal to columnar basal cells have large oval nuclei arranged vertical to the surface but do not form a distinct row. The epithelium contains numerous rete pegs and many pigment granules (Plate XIX). The cells of the stratum granulosa are closely arranged and contain distinct granules. Behind the mucocutaneous junction, squamous cells are gradually reduced and replaced by low cuboidal cells. The total number of layers is also reduced. The tunica propria is almost negligible.

The tarsal conjunctiva consists of 3 to 4 layers of cells, flattened on the surface and cuboidal towards the base (Plate XX). This observation differs with the description given by Prince et al. (1960) and Trautmann and Fiebiger (1957). According to Prince et al. (1960) the tarsal conjunctiva in domestic animals consists of two layers of cells, the superficial being columnar and the deep one cuboidal, and according to Trautmann and Fiebiger (1957), it is stratified columnar in the horse and carnivora and transitional in ruminants and swine. The tarsal conjunctiva contains a few goblet cells and its basal cells do not form a distinct row. The glands of Wolfring and Henle, which were described by Wolff (1955) in man, are absent in sheep. However, in some specimens scattered short thick epithelial rete pegs are seen in this area (Plate XX). The scanty substantia propria contains dense collagenous and fine reticular and elastic fibers and lymphocytes.

The post-tarsal conjunctiva is most variable. In some areas it is stratified squamous, at others stratified cuboidal to columnar, and at a few places transitional. Near the fornix, the cell layers and goblet cells increase in number. The basal cells are cuboidal with large oval nuclei vertical to the surface and are arranged in a row. The tunica propria becomes thicker and contains variable numbers of free lymphocytes and lymph nodules (Plates XXII and XXIV).

The fornix-conjunctiva is also very variable. In some specimens numerous large goblet cells are present and hence the epithelium appears stratified columnar. In others, a few small goblet cells and more cuboidal cells are found and the epithelium becomes stratified cuboidal (Plate XXIII). These variations are observed even in the same individual. The basal cells are generally arranged in a distinct row. The substantia propria is well developed at the fornix and consists of two layers: the adenoid and fibrous. The adenoid layer is composed of a fine reticulum of connective tissue which contains abundant lymphocytes and many lymph nodules (Plates XXIV and XXV). The fibrous layer is thick and composed of coarse collagenous and elastic fibers. It is continuous with the subconjunctival tissue and contains many fat cells. Because of an abundance of loose areolar tissue, the conjunctiva always presents folds of variable sizes (Plate XXIV).

The scleral conjunctiva is loosely attached to the sclera and is composed of stratified cuboidal epithelium having 6-7 layers of cells towards the fornix and 10-15 layers at the sclero-corneal junction. The surface cells are cuboidal towards the fornix and flattened towards the limbus. The intermediate cells are polyhedral and contain large spherical nuclei. The basal cells are columnar with large elongated vertical nuclei which appear under low power as a dark line. This is the characteristic feature of the limbal conjunctiva. The goblet cells gradually decrease in number from the fornix to the limbus. At the limbus the conjunctiva always presents a thickening, a few rete pegs of variable sizes and some pigment (Plate XXVI). The glands of Manz which were reported in sheep in 1859 by Strohmeyer cited by Aureli (1957) and in lambs by Wolff (1955) are not present in the sheep under investigation. These glands may be represented by the rete pegs at the limbus. The substantia propria is like that of the fornix except lymphocytes and lymph nodules are gradually reduced in number and

finally disappear near the limbus. At the limbus the substantia propria forms connective tissue papillae, the interspaces of which are filled with epithelial rete pegs.

The corneal conjunctiva is intimately fused with the well-developed substantia propria of the cornea and forms the corneal epithelium. It is 50 μ thick and composed of stratified squamous epithelium with 10-12 layers of cells. The borders of the epithelium are uniform, straight and parallel. The basal cells are columnar with elongated nuclei arranged vertical to the surface and appear as a dark line as in the limbus at low power. The epithelium rests on a homogenous membrane (Bowman's membrane).

The conjunctiva of goats resembles that of sheep with a few variations which follow: the palpebral conjunctiva generally presents some rete pegs of variable sizes. These pegs have depression towards the surface. In the tarsal and post-tarsal conjunctiva of some specimens, there are a few large epithelial "buds" composed of large polygonal cells (Plate XXI). It differs with the gland of Henle which was described by Wolff (1955) in man for it does not resemble the gland of Lieberkuhn of the large intestine. The fornix and scleral conjunctivae appear to contain at certain areas transitional epithelium. Lymph nodules are few in number. The limbal conjunctiva is thickened and contains less developed rete pegs (Plate XXVII). Since only four goats were examined, these observations require further investigation.

Histochemistry - With alcian blue and PAS reagent, goblet cells appear as mucous secreting glands. The basement membrane of the conjunctiva is less PAS positive than the dermo-epidermal junction. Similar reactions are noted in the goat.

LACRIMAL CARUNCLE (CARUNCULA LACRIMALIS)

Gross - The caruncle of sheep is a small rounded generally pigmented prominence situated in the medial canthus (Plate I). It becomes distinct when the eyeball is rotated laterally. It contains a few fine hairs. It receives blood from the medial palpebral arteries and nerves as in the palpebrae.

Histology - The caruncle is covered with modified skin (caruncular conjunctiva) which is composed of stratified squamous epithelium and dermis. The epithelium near the nictitating conjunctiva contains goblet cells, singly and also in groups (Plate XXVIII). There are well-developed lobulated sebaceous glands similar to the glands of Zeis and a few sweat glands near the base (Plate XXVIII). The substantia propria contains some lymphocytes. Near the base are also a few striated muscle fibers. The caruncle of goats is similar to that of sheep.

THIRD EYELID (NICTITATING APPARATUS)

Gross - The third eyelid is composed of a conjunctiva covering a central core of cartilage and gland (Plates XXIX and XXXII). Developmentally the structures of the eyelid proper and the third eyelid are derived from the same embryonic layers. As all structures of the third eyelid act as an apparatus for nictitation, it is considered here as the nictitating apparatus which consists of the nictitating membrane, cartilage and glands. Sisson and Grossman (1953) also considered the nictitating membrane a part of the third eyelid, not a synonym for it.

The nictitating membrane is a semilunar fold of the conjunctiva based on hyaline cartilage and situated in the medial canthus (Plates I and XXIX). It is pale red in color and pigmented at the margin. Both surfaces are covered with the conjunctiva (nictitating conjunctiva).

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The nictitating membrane forms two fornices: the deep one is between the membrane and eyeball, and the superficial one is between it and the eyelids (Plate XXXII). The outer border is concave, thick and generally pigmented. The upper and lower angles and borders are continuous with the conjunctivae of the superior and inferior palpebral fornices.

The nictitating cartilage is a flat, curved, 'T' shaped structure forming the core of the third eyelid. It has two surfaces: the deep one is concave to adapt to the eyeball and the superficial one is convex. The head of the cartilage is thin and lies in the nictitating membrane extending along its free border. The shaft of the cartilage is thick and long and lies between the medial side of the eyeball and the orbit. It is surrounded by the gland of the third eyelid.

The nictitating glands (glands of the third eyelid) in some animals are two in number: superficial and deep. As the deep nictitating gland (Harderian gland) is absent in sheep, the superficial nictitating gland (Glandula superficialis palpebrae tertiae) is described here simply as the nictitating gland. The nictitating gland of sheep surrounds the shaft of the cartilage and is embedded in the orbital fat. It is thicker on the superficial surface than on the deeper surface of the cartilage. It is about 24 mm long, 12 mm wide and 4.5 mm thick.

The third eyelid receives its blood supply through the nictitans artery which is a branch of the malar artery. It is innervated by the infratrochlear branch of the nasociliary nerve which is a branch of the ophthalmic division of the trigeminal nerve. The third eyelid of goats is thinner and longer than in sheep but otherwise the same (Plate XXX).

Histology - The nictitans conjunctiva is also irregular in structure like that of the palpebral conjunctiva. Generally it is composed of stratified cuboidal epithelium but in some specimens it appears transitional in a few areas. The cells of all layers are cuboidal.

The epithelium on the palpebral side is $175\ \mu$ thick and consists of 6-7 layers of cuboidal cells, while on the bulbar side it is $125\ \mu$ thick and contains 4-5 layers of cuboidal cells. Generally, near the free border a few rete pegs are found on both surfaces. A folded prominence on the external surface and a corresponding groove on the internal surface are observed (Plate XXIX). Pigment granules are more numerous near the free border. Goblet cells are present on both surfaces but they are more numerous in the grooves on the dorsal surface. The substantia propria is similar to that of the fornix and consists of two layers: the adenoid and fibrous. The adenoid layer contains an abundance of lymphocytes and many lymph nodules which are more numerous on the deep surface of the nictitating membrane (Plate XXXI). The fibrous layer is composed of coarse collagenous and fine elastic fibers and contains large blood vessels more numerous on the bulbar surface of the membrane. Smooth muscle was observed at the base.

The nictitating cartilage is hyaline in structure. It is surrounded by a well-developed perichondrium which is composed of dense collagenous and a few fine elastic fibers. The perichondrium sends septa into the surrounding nictitans gland (Plate XXXII).

The nictitating gland (Glandula superficialis palpebrae tertiae) is a tubuloalveolar mixed gland in sheep (Plates XXXII, XXXIII and XXXIV). It is surrounded by a capsule which sends trabeculae into the parenchyma of the gland and divides the gland into lobules. The septa contain blood vessels, nerves, interlobular ducts and at some places fat cells (Plates XXXII, XXXIII and XXXIV). The gland is mixed with the mucous acini located mostly near the trabeculae and at the periphery of the lobule and gland (Plate XXXII). Mucous alveoli contain large central lumens filled with homogeneous material and resemble transversely cut interalveolar ducts. Some branching alveoli are also present. Interalveolar spaces contain many plasma cells (Plate XXXIV).

The interlobular ducts are lined with a single layer of cuboidal cells resting on a basement membrane. Large ducts are lined by stratified columnar epithelium having 3-4 layers of cells and many goblet cells (Plates XXXI and XXXIII). The main duct runs on the deep aspect of the cartilage and opens on the deep surface of the membrana nictitans just in front of the deep fornix (Plates XXXI and XXXIII).

The microscopic structure of the nictitating apparatus of goats is similar to that of sheep except the following differences: both surfaces are lined by stratified squamous epithelium containing 6-7 layers of cells on the external surface and 4-5 layers on the bulbar surface (Plate XXX). Lymph nodules are absent on the external surface but are present on the ventral surface near the fornix where the duct of the nictitans gland opens (Plate XXXV). Variable numbers of lymphocytes are present in the tunica propria of both surfaces. The nictitans gland is a compound tubuloalveolar, mixed (seromucous) gland, and as in sheep contains plasma cells in the interalveolar spaces (Plate XXXVI).

Histochemistry - The frozen sections of the gland stained with Sudan black give a very weak reaction for lipids. Scattered fine black globules appear in the cytoplasm of the glandular cells. Interlobular fats stain deep black. With Nile blue sulfate the cytoplasm stains pale blue, while the nuclei stain deep blue. The alkaline phosphatase activity is stronger in the vicinity of the basement membrane. The reaction for acid phosphatase is weak. In paraffin sections, with periodic acid Schiff reagent two types of glandular cells, PAS positive and PAS negative are present (Plate XXXIV). With alcian blue two types of cells, mucous and serous, are observed (Plate XXXII). The cytoplasm is stained blue in mucous cells and light pink in serous cells while nuclei of both cells stain pink. These histochemical observations suggest that the gland is mixed and its secretion is mostly seromucous. Similar reaction occurs in the goat (Plate XXXVI).

PERIORBITA (ORBITAL PERIOSTEUM)

Gross - The periorbita (orbital periosteum) of sheep is a conical fibrous sheath which lines the orbit and encloses the eyeball with its muscles, vessels, nerves and associated fat (Plates II and III). Except at the orbital margin, suture lines, foramen and lacrimal fossa, it is loosely attached to the wall of the orbit. It is thickened around the optic foramen to form a fibrous ring (Annulus of Zinn) which gives origin to the recti and retractor muscles. It becomes continuous through the optic and ethmoidal foramen with the cranial periosteum (periosteal dura). It is also thickened at the orbital margin to form the Arcus marginale from where it is continuous with the superior and inferior palpebral fascia (orbital septum) in the corresponding lids and with the periosteum of the adjacent facial bones (Plate XXXVII). From the inferior surface of the periorbita, numerous septa extend into the various structures surrounding the eyeball. At the posterior limit of the lacriaml fossa it splits to enclose the lacrimal gland. The periorbita also gives attachment to the trochlear cartilage which acts as a pulley for the superior oblique muscle. The periorbita also transmits blood vessels, lymphatics and nerves to the wall of the orbit. It is pierced by the vessels and nerves entering and leaving the orbit. The periorbita of the goat is similar to that of sheep.

Histology - The periorbita is composed of two layers: the outer and inner. The outer layer is thicker and contains loose collagenous bundles and connective tissue cells and attaches to the wall of the orbit by loose areolar tissue. The inner layer is thinner and contains dense collagenous fibers which reflect over the vessels and nerves entering the orbit. The microscopic structure of the periorbita of goats is similar to that of sheep.

ORBITAL FASCIA

Gross - The orbital fascia includes the bulbar fascia (Tenon's capsule) and muscular fasciae (Plates II and III). The bulbar fascia is a thin membrane which covers the sclera and separates the eyeball from the surrounding orbital fat, muscles and other structures. Anteriorly the bulbar fascia is attached to the sclero-corneal junction below the limbal conjunctiva and posteriorly at the entrance of the optic nerve (Plates II and III). It reflects as a tubular sheath over the muscles and is perforated anteriorly by the tendons of the ocular muscle, at the equator by the vorticosse veins and posteriorly by the ciliary vessels and nerves. The thickened ventral part of the bulbar fascia which is called the ligament of Lockwood is attached laterally and medially to the periorbita by poorly developed lateral and medial ligaments. Each ocular muscle surrounding the eyeball is covered by thin fibrous sheaths called muscular fasciae which are extensions of the bulbar fascia (Plates II and III). The orbital fascia of goats does not differ from that of sheep.

Histology - The bulbar fascia is composed of fine collagenous, reticular and a few elastic fibers. Its bulbar surface is loosely attached to the episclera by fine connective tissue trabeculae and aids the movements of the eyeball (Plate XXXVIII). Histologic structure of the bulbar fascia in goats is similar.

EXTRINSIC OCULAR MUSCLES

Gross - The extrinsic ocular muscles of sheep are four recti, two oblique and one retractor (Plates II and III). The general gross anatomy of the striated extrinsic ocular muscles of sheep is in agreement with descriptions given for other domestic animals by Ellenberger and Baum (1943), Prince et al. (1960) and Sisson and Grossman (1953).



Nerves and blood supply to striated extrinsic ocular muscles are in agreement with the report given by Prince et al. (1960) and Sisson and Grossman (1953). Extrinsic ocular muscles in goats are similar to those of sheep.

Histology - The extrinsic ocular muscles of sheep are less differentiated and show poor striation. An abundance of nerve fibers is seen among these muscle bundles. Microscopically these muscles in the goat do not differ from those of sheep.

LACRIMAL APPARATUS

The lacrimal apparatus of sheep consists of the lacrimal gland, excretory ducts, Puncta lacrimalia, lacrimal canaliculi, lacrimal sac and nasolacrimal duct.

Lacrimal Gland

Gross - The lacrimal gland of sheep is a flattened, oval, pale red, modified cutaneous gland situated within a special division of the periorbita between the dorsolateral aspect of the eyeball and the supraorbital process of the frontal bone (Plates II and III). The gland is situated more laterally than in other domestic animals. It is moulded to conform with the eyeball and bony orbit. It is about 1.64 gm in weight, 2.8 cm long, 2 cm wide and 0.5 cm thick. The gland has two surfaces: the superior (orbital) and inferior (bulbar), two borders: the anterior (palpebral) and posterior and two extremities: the lateral and medial. The superior surface is convex and is adapted to the wall of the orbit and it is divided into the orbital and palpebral parts by a shallow groove formed by the orbital margin. The periorbita covering the orbital part is generally pigmented. The inferior surface is concave fitting over the eyeball from which it is separated by the inner layer of the periorbita, the aponeurosis of the levator palpebrae and



external rectus muscles. When the periorbital covering is removed both surfaces appear lobulated. The palpebral margin is thin and extends into the base of the superior eyelid. The posterior border is more rounded and is embedded into the orbital fat. Both extremities are rounded, the lateral being extended up to the lateral palpebral commissure and the medial up to the middle of the orbit. The blood supply comes through the lacrimal artery which is a branch of the superficial temporal artery (Plate V). The lacrimal artery enters the gland and divides into lobular, interlobular and alveolar arteries (Plate VIII). It is innervated by the lacrimal nerve which is a branch of the ophthalmic division of the trigeminal nerve. This observation is in agreement with the findings of Prince et al. (1960). Grossly the lacrimal gland of goats resembles that of sheep.

Histology - The lacrimal gland of sheep is a tubuloalveolar mixed gland similar to the nictitans gland and submaxillary salivary gland (Plates XL and XLI). It is surrounded by a connective tissue sheath which sends septa into the substance of the gland dividing it into lobules. The septa are composed of dense collagenous and a few elastic fibers and contain some smooth muscle fibers, blood vessels, nerves and ducts (Plates XL and XLIV). The lacrimal gland is related ventrally to a smooth muscle band (Plate XXXIX). The interalveolar space contains plasma cells, some fat cells and lymphocytes (Plate XLI). The presence of plasma cells was reported in the lacrimal gland of cattle by Sundwall (1916) and in the human lacrimal gland by Hannes (1911). Lobules are made up of serous and mucous alveoli similar to those of the nictitans gland. Intercellular secretory canaliculi are found in some alveoli. Smaller ducts such as alveolar and intercalated and intralobular ducts are lined with a single layer of cuboidal epithelium which resembles the epithelium of alveoli. The medium sized ducts such as lobular and interlobular ducts are lined with



stratified cuboidal epithelium containing some goblet cells (Plate XLIV).

The lacrimal gland of goats is a compound tubuloalveolar mixed gland (Plate XLII). Lobules vary greatly in shape and size. Interlobular septa are thin and contain many ducts and plasma cells (Plate XLIII). In medium sized ducts, goblet cells are absent.

Histochemistry - Histochemically as well as microscopically the structure of the lacrimal gland of sheep is similar to that of the nictitans gland. The only difference noticed is that the lacrimal gland contains more mucous alveoli than the nictitans gland. Mucous alveoli are more at the periphery of the lobule and the gland (Plate XL). With alkaline and acid phosphatase, Sudan black, Nile blue sulfate, periodic acid Schiff reagent, and alcian blue, the gland reacts as does the nictitans gland. The luminal contents are strongly PAS positive. These observations suggest that the gland is a mixed one and secretes a sero-mucous substance (Plates XL and XLI). These findings also support the statement of Kingsley (1917), and Prince (1956) that phylogenetically the lacrimal and nictitans glands developed together and in the evolutionary process they separated into two glands. Observations made on the lacrimal gland of goats agreed with those on sheep (Plates XLII and XLIII).

Lacrimal Excretory Ducts

Gross - Two large and 4-5 small excretory ducts are present in sheep. These ducts leave the gland on the ventral surface near the palpebral margin, pierce the periorbita lining the ventral surface of the gland, run towards the dorsolateral fornix conjunctivae, enter the base of the superior eyelid and open on its conjunctiva surface in front of the fornix (Plates II, III, IV and XLVI). These openings in sheep resemble the openings of excretory ducts in ox observed by Sundwall (1916)

and in the horse reported by Smythe (1956). The number of excretory ducts of goats is the same as in sheep.

Histology - The lacrimal excretory ducts of sheep consist of two layers: the epithelium and substantia propria. The epithelium is composed of stratified columnar cells having numerous goblet cells which give positive reaction with alcian blue and PAS reagent (Plate XLV). In the epithelial wall many vacuoles which appear as intraepithelial scattered goblet cells in H. and E. Stain, do not stain with either alcian blue or PAS reagents. The substantia propria is composed of dense collagenous tissue. The diameter of the duct varies from 60-80 microns. These lacrimal excretory ducts of sheep resemble the duct of the mandibular salivary gland which contains many goblet cells near its buccal opening (Trautmann and Fiebiger, 1957). The microscopic structure of the excretory ducts of goats are similar (Plate XLVII).

Puncta lacrimalia

Gross - Both Puncta lacrimalia are present in sheep. They are small slit-like openings situated on a prominence on the ventral aspect of the lid margin very close to the medial canthus (Plates III and IV). Both puncta are not situated at the same distance from the canthus and they do not come in contact when the eyelids are closed.

Histology - They are lined with the continuation of the marginal conjunctiva. The epithelium is composed of nonkeratinized, nonpigmented stratified squamous cells. The openings are surrounded by fibrous tissue derived from the tarsus. The Puncta lacrimalia of goats are similar.

Lacrimal Canaliculi

Gross - The lacrimal canaliculi (ductus lacrimalis) of sheep, upper and lower, start from the puncta, run first vertically, then

horizontally in the substance of the lid margin, converge towards the medial commissure, pierce the periorbita and finally open into the lacrimal sac (Plates IV and VI). Near the medial commissure both puncta are attached to the medial palpebral ligament in front and Pars lacrimalis (Horner's muscle) behind.

Histology - The canaliculi consist of two layers: the epithelium and substantia propria. The epithelium is stratified squamous to cuboidal near the puncta and stratified columnar elsewhere and contains 6-7 layers of cells (Plate XLVIII). A few goblet cells are present near the lacrimal sac in some specimens. The tunica propria is composed of dense collagenous and some elastic fibers which mostly parallel the duct wall. A few fibers of the orbicularis oculi surround the puncta here and there. The apical projection, the luminal contents and base of the duct are PAS positive. This observation suggests that tears of sheep contain mucopolysaccharide.

The canaliculi of goats are lined with stratified squamous epithelium near the opening and stratified columnar near the lacrimal sac. Free lymphocytes are found in the substantia propria and in the epithelium. A few goblet cells are seen near the lacrimal sac as in sheep.

Lacrimal Sac

Gross - The lacrimal sac of sheep is situated in the lacrimal fossa which leads into the osseous nasolacrimal canal. The sac is blind dorsally, receives both canaliculi laterally and continues down into the nasolacrimal duct (Plates IV and VI). The sac is enclosed by a special compartment of the periorbita which is called the lacrimal fascia. A venous plexus surrounds the lacrimal sac and continues over the nasolacrimal duct (Plate LII). The sac is dorso-posterior to the Pars lacrimalis (Horner's muscle). It is supplied by blood

through the branches of the malar artery. It is innervated by the infratrochlear nerve.

Histology - The sac consists of two layers: epithelium and substantia propria. The epithelium is generally composed of stratified columnar epithelium having 4-5 layers of cells and some goblet cells (Plates XLIX, L and LI). At a few areas pseudostratified epithelium is also present. In some specimens, the basal epithelium is invaded by the connective tissue pigment cells (Plate XLIX). Goblet cells are mostly single although a few are grouped into an intraepithelial gland (Plate LI). Many vacuoles are found in the epithelial wall. The substantia propria is well-developed, highly vascular and contains a venous plexus resembling erectile tissue.

In goats, the epithelium of the lacrimal sac appears at one place stratified cuboidal, at others pseudostratified, and at certain spots, transitional. Goblet cells are similar to those of sheep. The substantia propria contains many free lymphocytes. Histochemical reactions are similar to those of sheep.

Nasolacrimal Duct

Gross - The nasolacrimal duct of sheep originates from the lacrimal sac, first passes through the osseous lacrimal canal, then the osseous lacrimal groove of the maxilla. At first it is covered by a plate of cartilage, then by the mucous membrane of the middle meatus and finally passes through the terminal fold of the ventral turbinate to open on the nasal mucous membrane above the nostril (Plate VI).

Histology - Like the lacrimal sac the wall of the duct consists of the epithelium and substantia propria. The epithelium is generally composed of stratified columnar cells (Plates LII, LIII, LIV and LV). At certain areas pseudostratified epithelium is also observed. Near

the nasal opening the epithelium is 25 μ thick and contains 6-8 layers of cells and abundant goblet cells (Plate LVI). At the middle of the duct, the epithelium is 20 μ thick and contains 5-6 layers of cells. Near the lacrimal end the epithelium is 12.5 μ thick and contains 3-4 layers of cells. The substantia propria resembles the lamina propria of the nasal mucous membrane. It is composed of coarse collagenous fibers and contains an abundant venous plexus resembling erectile tissue (Plates LIII, LIV, LV and LVI). The substantia propria of the lower half of the nasolacrimal duct where it is covered by the nasal mucous membrane is surrounded by seromucous glands (Plate LV). The observation of the venous plexus around the lacrimal sac and nasolacrimal duct resembles the finding of Minamikawa (1958) in the rabbit, dog, cat, mouse, guinea pig, bat and mole. There are no lymph nodules in the substantia propria of the duct of sheep. The nasolacrimal duct of goats is similar to those of sheep (Plates LVII and LVIII).

Histochemistry - The cell membrane, goblet cells and luminal contents are PAS positive. The glands surrounding the nasolacrimal duct when stained with alcian blue and PAS reagent appear as seromucous glands. Many vacuoles similar to those of the lacrimal excretory ducts are also found in the epithelium of the nasolacrimal duct. With the help of alcian blue and PAS reagents, they are found not to be goblet cells, but to be vacuoles only (Plate LVI). The nasolacrimal duct of goats gives histochemical reactions similar to those of sheep.



PLATE I

Eye of sheep: External adnexa

(1) Eyebrow: long sensory and a few ciliary hairs, (2) Upper eyelid with long dense cilia, (3) Lower eyelid with short cilia and long sensory hairs, (4) Lateral palpebral commissure, (5) Medial palpebral commissure and groove, (6) Lacrimal pouch, (7) Bulbar conjunctiva visible through palpebral fissure, (8) Membrana nictitans, (9) Caruncle.



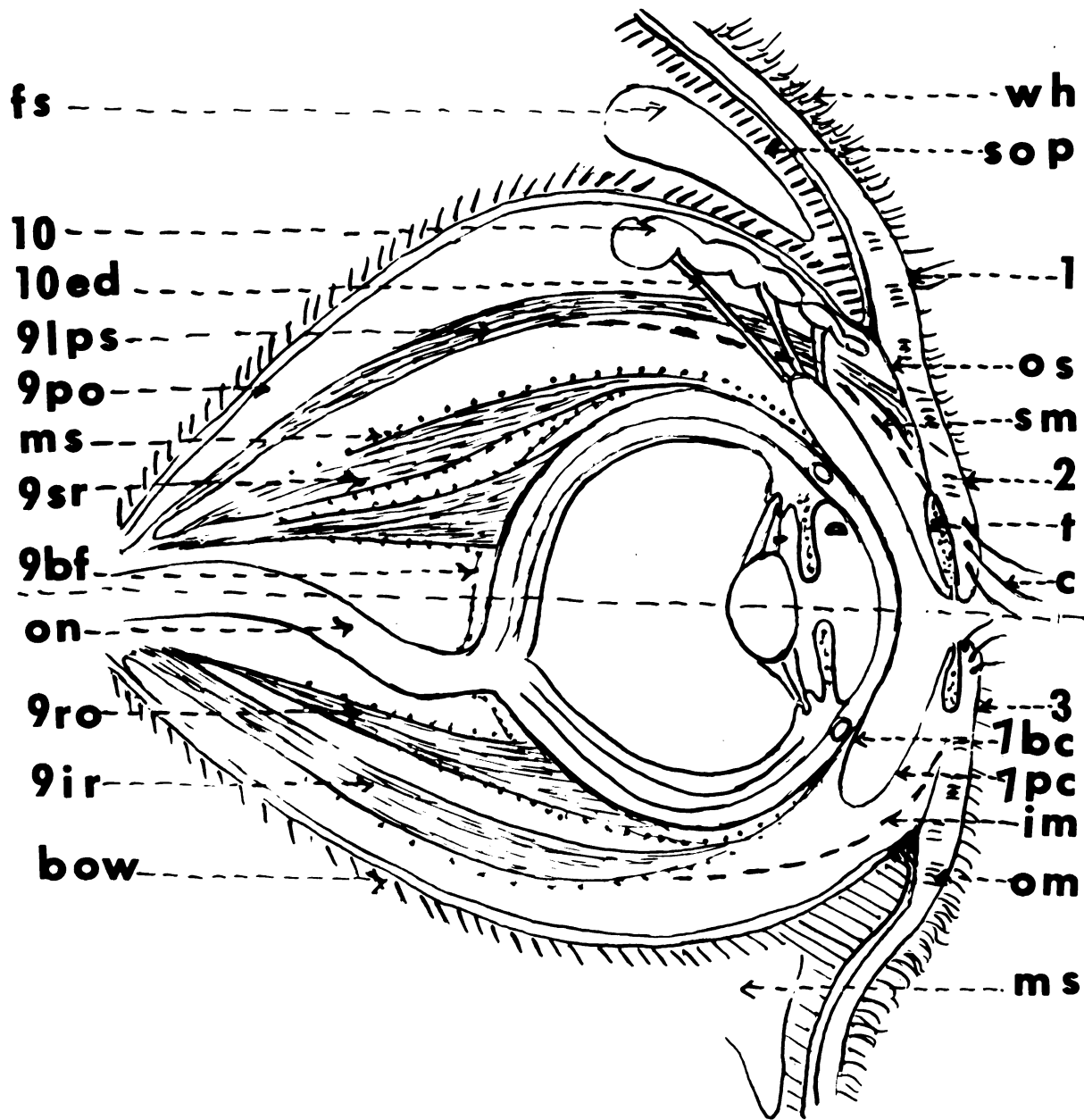


PLATE II

Diagram of the vertical section of the eye of sheep

Specimen areas: (1) Eyebrow, (2) Upper eyelid, (3) Lower eyelid, (7pc) Palpebral conjunctiva, (7bc) Bulbar conjunctiva, (9 lps) Levator palpebrae superioris, (9po) Periorbital, (9sr) Superior rectus, (9bf) Bulbar fascia, (9ro) Retractor oculi, (9ir) Inferior rectus, (10) Lacrimal gland, (10ed) Lacrimal excretory duct

Related structures: (wh) Wool hair, (sop) Supra orbital process, (so) Orbital septum, (sm) Superior muscle of Müller, (t) Tarsal gland, (c) Cilia, (im) Inferior muscle of Müller, (om) Orbicularis oculi muscle, (ms) Maxillary sinus, (fs) Frontal sinus, (ms) Muscular sheath, (on) Optic nerve, (bow) Bony orbital wall

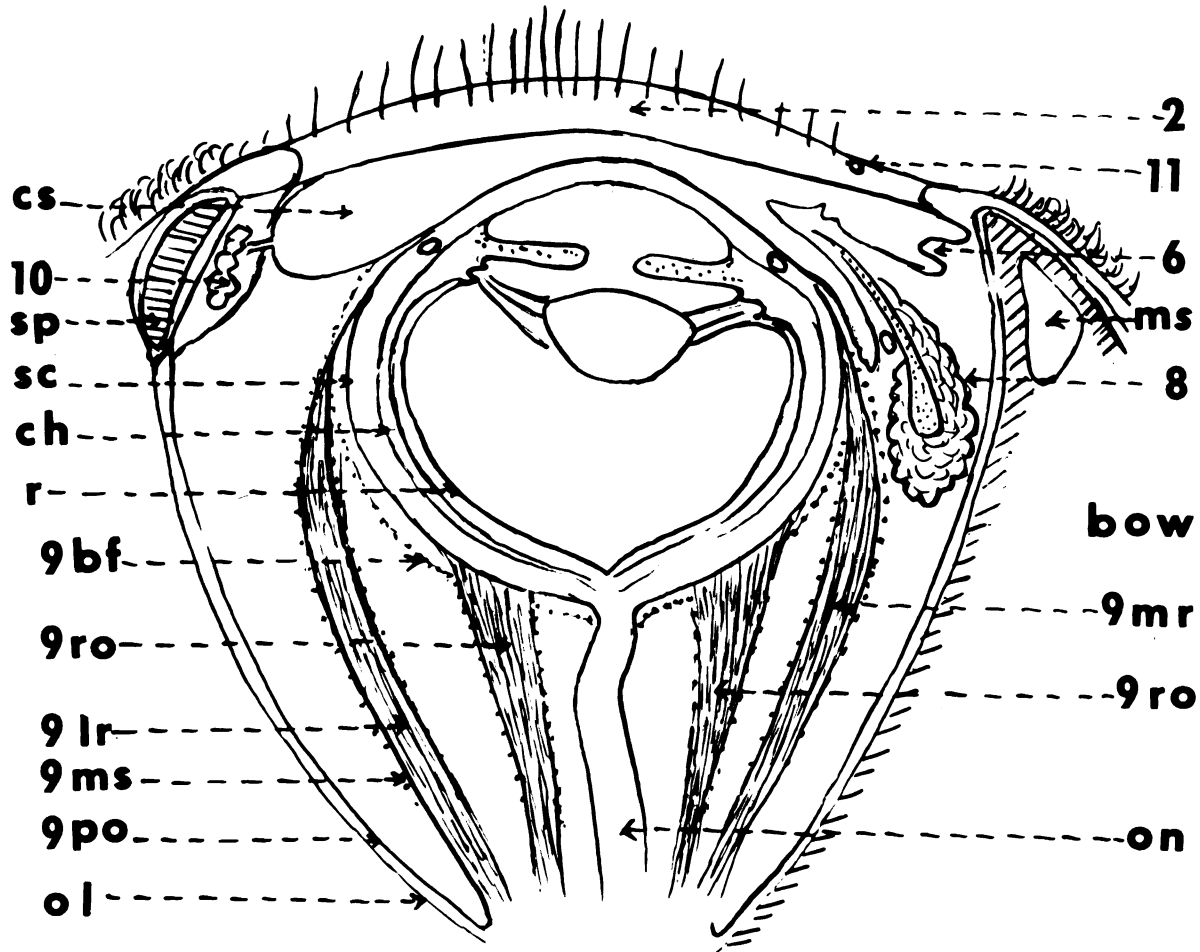


PLATE III

Diagram of the horizontal section of the eye of sheep

Specimen areas: (2) Upper eyelid, (6) Caruncle, (8) Nictitating apparatus, (9mr) Medial rectus, (9ro) Retractor oculi, (9bf) Bulbar fascia, (9lr) Lateral rectus, (9ms) Muscular sheath, (9po) Periorbital, (10) Lacrimal gland, (11) Punctum lacrimale

Related structures: (ms) Maxillary sinus, (bow) Bony orbital wall, (on) Optic nerve, (cs) Conjunctival sac, (sp) Supraorbital process, (sc) Sclera, (ch) Choroid, (r) Retina, (ol) Orbital ligament



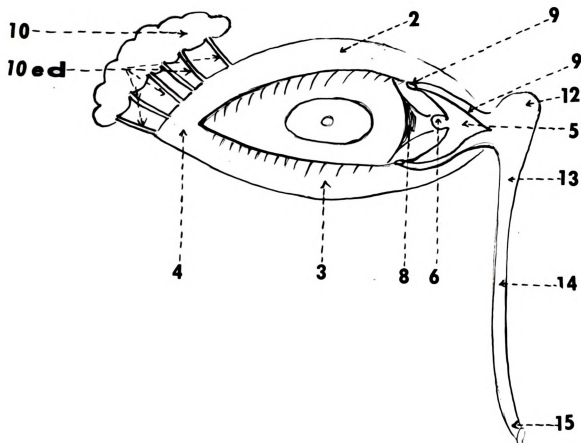


PLATE IV

Diagram of the lacrimal apparatus of sheep

Specimen areas: (2) Upper eyelid, (3) Lower eyelid, (4) Lateral commissure, (5) Medial commissure, (6) Caruncle, (8) Nictitating membrane, (9) Punctum lacrimale and lacrimal canaliculus, (10) Lacrimal gland, (10ed) Lacrimal excretory ducts, (12) Lacrimal sac, (13) Nasolacrimal duct, proximal portion, (14) Nasolacrimal duct, midportion, (15) Nasolacrimal duct, distal portion



PLATE V

Blood supply to the eye of sheep

Radiograph (reduced)

(1) Internal maxillary artery, (2) Malar artery, (3) Superficial temporal artery, (4) Lacrimal artery, (5) Bony orbit, (6) Eyeball, (7) External ophthalmic artery, (8) Frontal vein

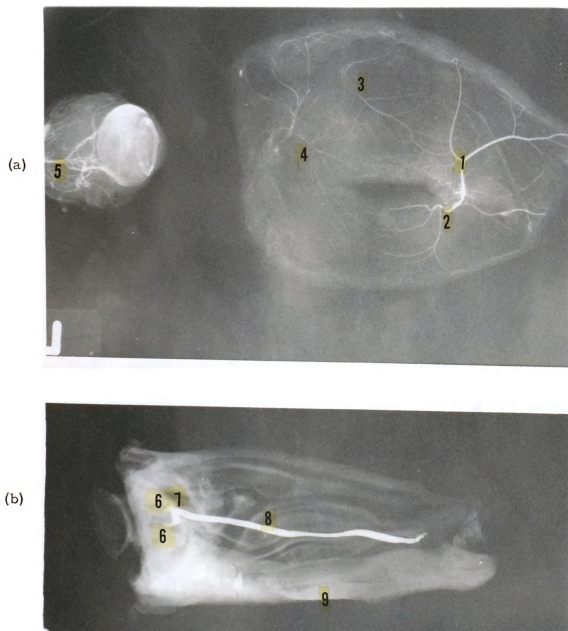


PLATE VI

- (a) Blood supply to the eyelids and eye muscles of sheep
Radiograph (reduced)
(1) Superior medial palpebral artery, (2) Inferior medial palpebral artery, (3) Superior lateral palpebral artery, (4) Lateral commissural artery, (5) External ophthalmic artery and muscles
- (b) Lacrimal passage of sheep
Radiograph (reduced)
(6) Lacrimal canaliculi, (7) Lacrimal sac, (8) Nasolacrimal duct, (9) Hard palate

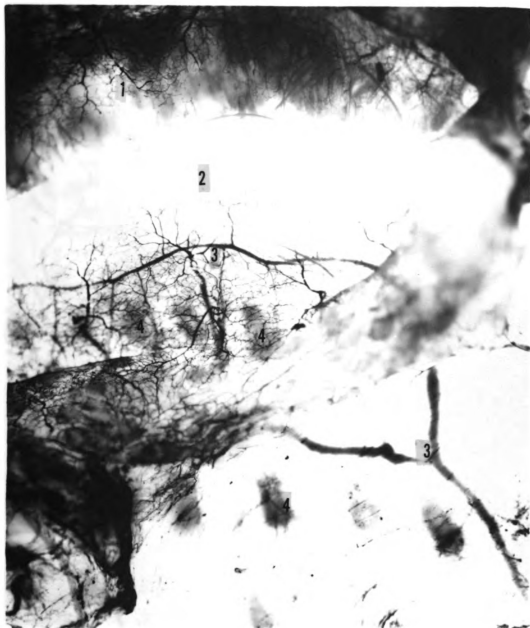


PLATE VII

Blood supply to the eyelids of sheep

India ink injected, 7X

(1) Branch from superior lateral palpebral artery, (2) Palpebral fissure, (3) Inferior medial palpebral artery, (4) Blood sinus of sensory hair of lower eyelid





PLATE VIII

Blood supply to the lacrimal gland of sheep

India ink injected, 11X

(1) Lobular lacrimal artery, (2) Inter-alveolar artery, (3) Intra-alveolar artery, (4) Alveolus

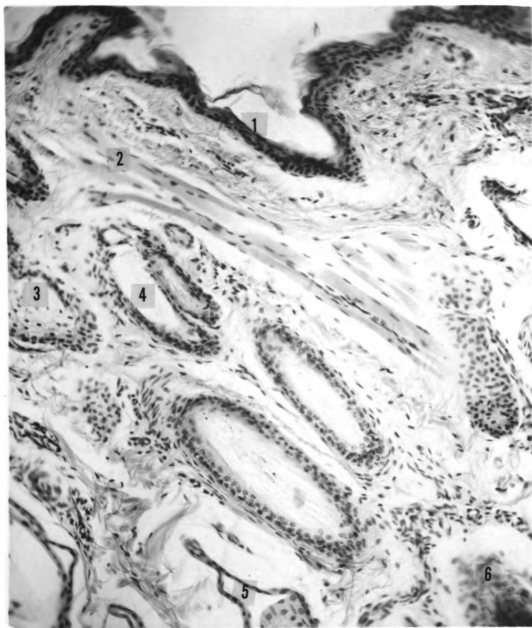


PLATE IX

Skeletal muscle fibers inserting into the skin of the eyebrow of the sheep

Vertical section, H. and E. Stain, 236X.

(1) Stratified squamous epithelium, (2) Frontalis muscle fibers, (3) Sebaceous gland, (4) Wool hair, (5) Sweat gland, (6) Bulb of the supercilium

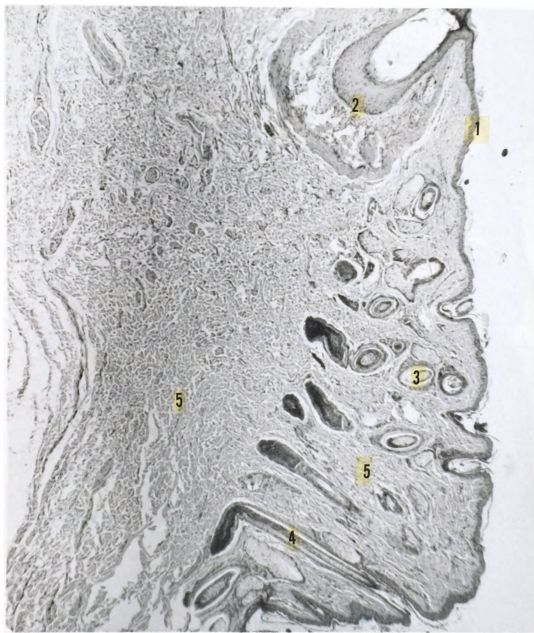


PLATE X

Eyeblink of the goat

Vertical section, H. and E. Stain, 48X

(1) Stratified squamous epithelium, (2) Sinus hair, (3) Coat hair,
(4) Supercilium, (5) Dermis



PLATE XI

Tarsal glands of the upper eyelid of sheep

Frontal section, H. and E. Stain, 53X

(1) Marginal palpebral conjunctiva with rete pegs, (2) Tarsal glands, (3) Central duct lined with stratified squamous epithelium

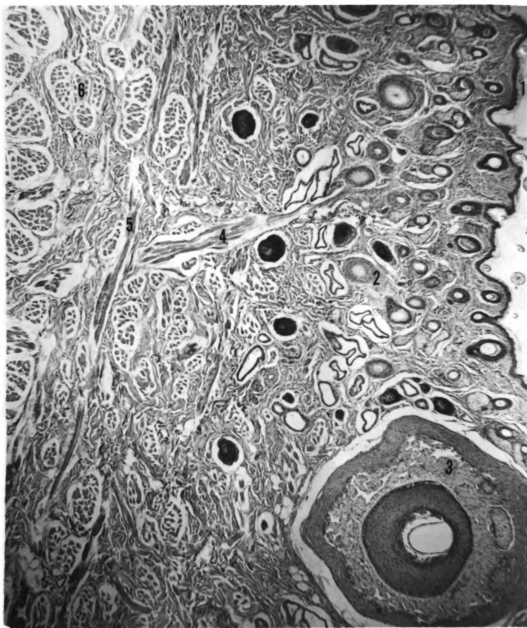


PLATE XII

Skeletal muscle arrangement in the upper eyelid of the goat
Oblique section, H. and E. Stain, 63X

- (1) Stratified squamous epithelium, (2) Coat hair, (3) Sinus hair,
(4) Levator palpebrae superioris muscle fibers, (5) Frontalis muscle
fibers, (6) Orbicularis oculi muscle fibers

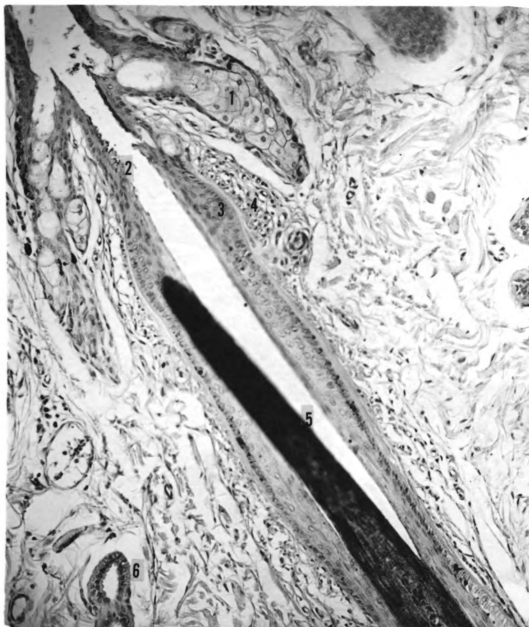


PLATE XIII

Ciliary follicle of the lower eyelid of sheep

Vertical section, Alcian Blue Stain, 240X

(1) Sebaceous gland,* (2) Follicular folds, (3) Thickened epithelium,
(4) Nerve plexus, (5) Root of cilia, (6) Gland of Moll

* Commonly termed gland of Zeis

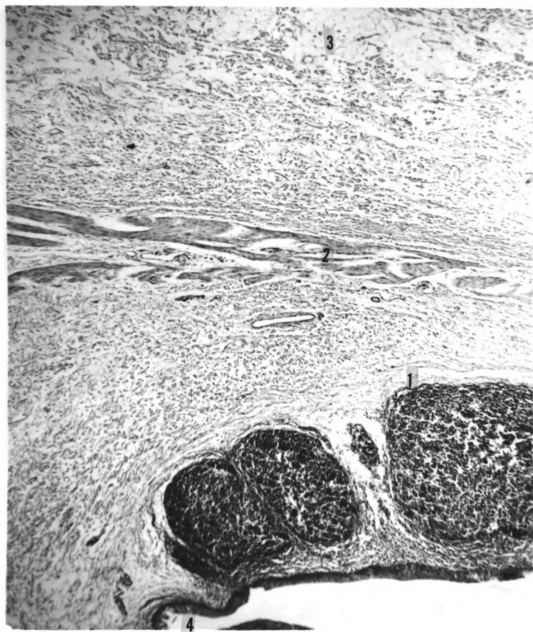


PLATE XIV

Lower eyelid of sheep

Vertical section, H. and E. Stain, 54X

(1) Lymph nodule, (2) Muscle of Müller, (3) Fat cells,

(4) Fornix conjunctiva

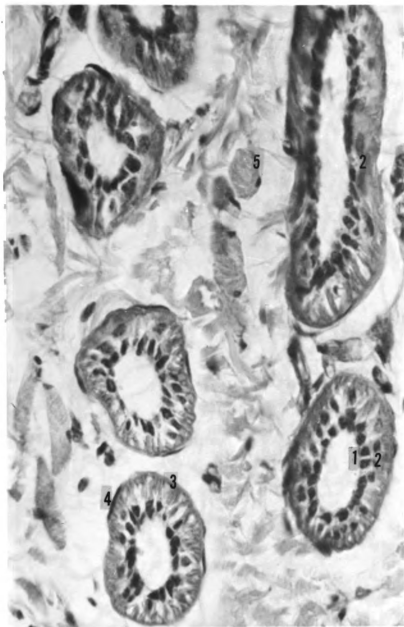


PLATE XV

Glands of Moll in the lower eyelid of sheep

Cross section, PAS reagent, 440X

(1) Cuboidal epithelium, (2) Myoepithelium, (3) PAS positive basement membrane, (4) Fibroblast, (5) Muscles of Riolo

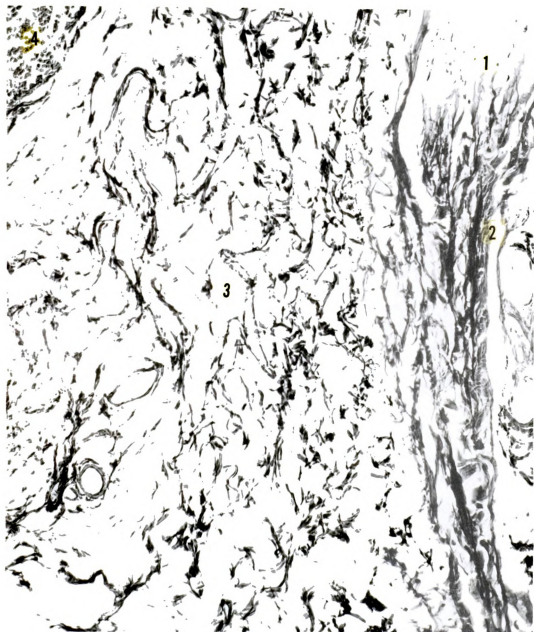


PLATE XVI

Muscles of Müller ending in elastic fibers in the lower eyelid of sheep

Vertical section, Weigert and Van Gieson's Stain, 225X

- (1) Muscle of Müller, (2) Elastic fibers, (3) Substantia propria,
(4) Lymph nodule near palpebral conjunctiva



PLATE XVII

Tactile hair of the lower eyelid of sheep

Transverse section at the level of sebaceous gland, Mallory's triple stain, 222X

(1) Tactile (sensory, sinus) hair, (2) Epithelial sheath, (3) Intra-epithelial terminal sebaceous lobule, (4) Fibro-elastic trabeculae, (5) Multilobulated sebaceous glands, (6) Outer connective tissue sheath





PLATE XVIII

Lacrimal (infraorbital) pouch glands of sheep
Vertical section, H. and E. Stain, 50X

(1) Stratified squamous epithelium, (2) Hair follicle, (3) Lacrimal pouch gland (modified multilobulated sebaceous gland), (4) Sweat gland, (5) Hair bulb



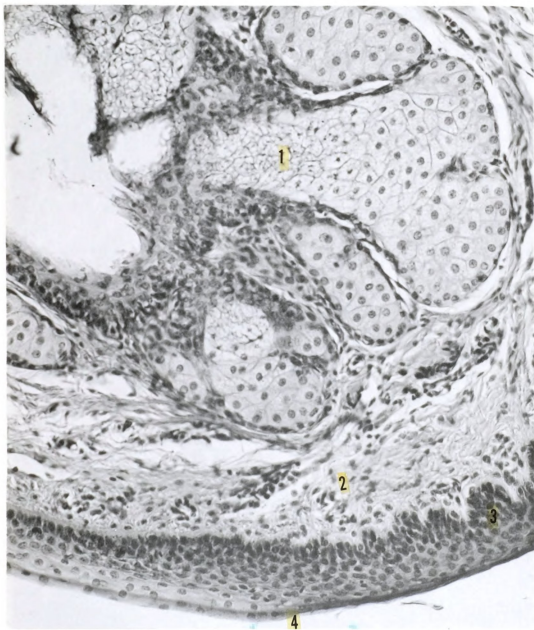


PLATE XIX

Upper palpebral marginal conjunctiva of sheep

Vertical section, H. and E. Stain, 324X

(1) Degenerating cells of tarsal (Meibomian) gland near the central duct lined by stratified squamous epithelium, (2) Tarsal gland capsule and substantia propria fused, (3) Stratified squamous marginal conjunctival epithelium with rete pegs, (4) Muco-cutaneous junction showing keratinized and nonkeratinized epithelium

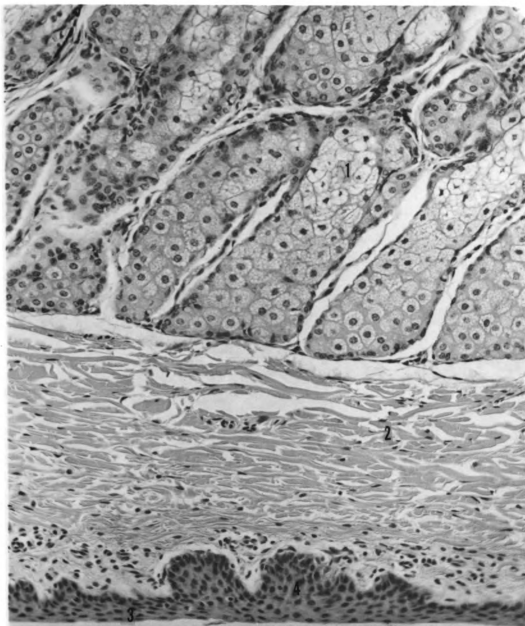


PLATE XX

Upper palpebral tarsal conjunctiva of sheep

Vertical section, H. and E. Stain, 277X

(1) Tarsal gland, (2) Tarsal capsule and substantia propria fused,

(3) Stratified squamous epithelium, (4) Conjunctival epithelial

rete peg

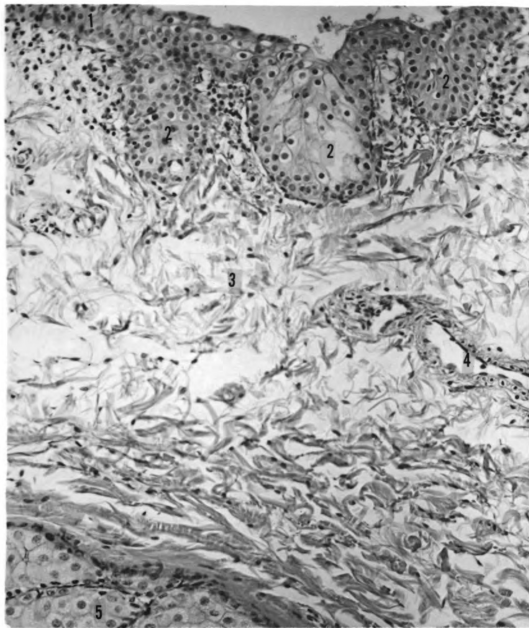


PLATE XXI

Upper palpebral tarsal conjunctiva of the goat

Vertical section, H. and E. Stain, 266X

(1) Tarsal conjunctiva, (2) Epithelial "buds," (3) Substantia propria, (4) Artery, (5) Tarsal (Meibomian) gland

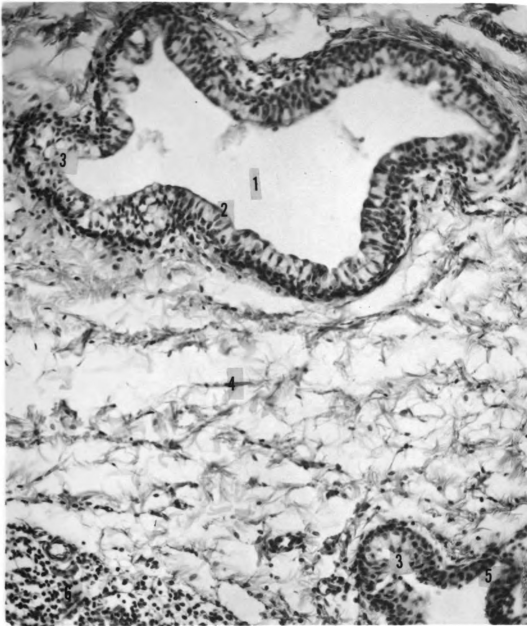


PLATE XXII

Upper palpebral post-tarsal conjunctiva and lacrimal excretory duct of sheep

Vertical section, H. and E. Stain, 267X

(1) Lacrimal excretory duct, (2) Stratified columnar epithelium, (3) Goblet cells, (4) Substantia propria, (5) Stratified cuboidal conjunctival epithelium, (6) Lymph node



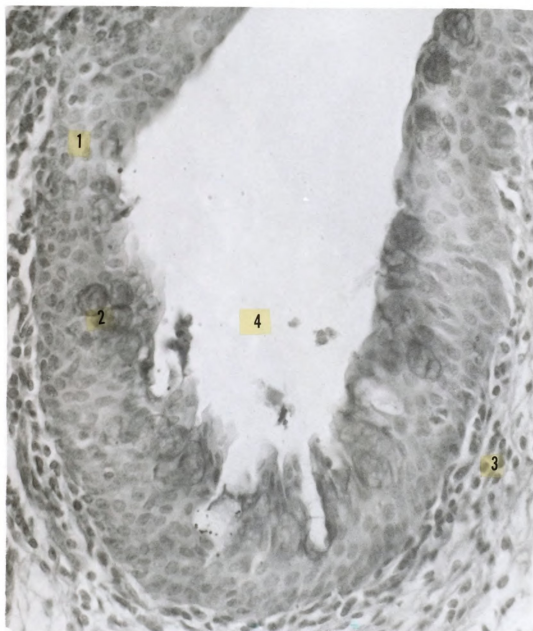


PLATE XXIII

Fornix conjunctiva of sheep

Vertical section, Alcian Blue Stain, 608X

(1) Stratified cuboidal epithelium, (2) Goblet cells, (3) Substantia propria containing lymphocytes, (4) Fornix



PLATE XXIV

Fornix and lower palpebral post-tarsal conjunctivae of sheep
Vertical section, H. and E. Stain, 49X

- (1) Stratified cuboidal post-tarsal conjunctival epithelium,
- (2) Substantia propria, (3) Lymph nodules, (4) Fornix,
- (5) Conjunctival fold, (6) Bulbar conjunctiva

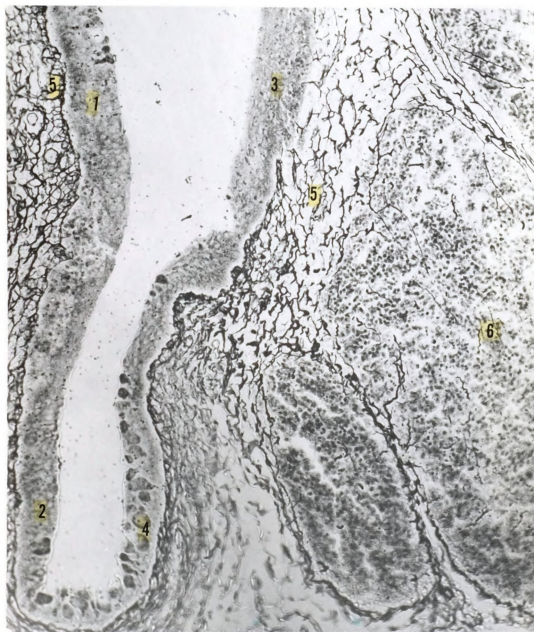


PLATE XXV

Reticular fibers in the fornix and lower palpebral post-tarsal conjunctivae of sheep

Vertical section, Gomori's reticular stain, 214X

(1) Post-tarsal conjunctiva, (2) Fornix conjunctiva, (3) Bulbar conjunctiva, (4) Goblet cells, (5) Reticular fibers, (6) Lymph nodule with reticular fibers

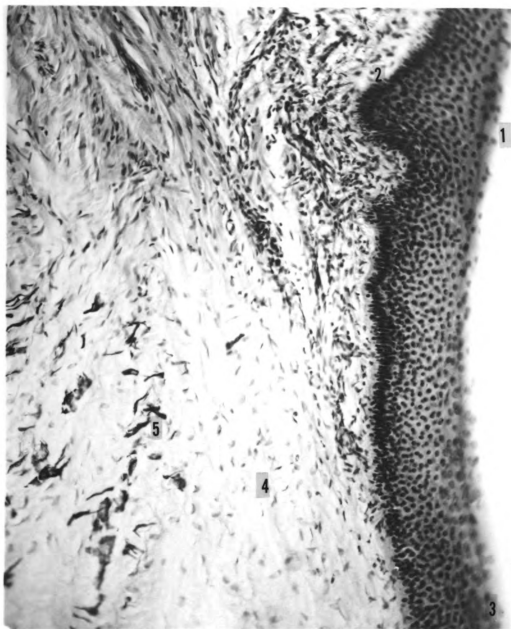


PLATE XXVI

Limbal conjunctiva of sheep

Vertical section, H. and E. Stain, 203X

(1) Limbal conjunctiva, (2) Conjunctival epithelial rete pegs,
(3) Corneal epithelium, (4) Sclera, (5) Connective tissue pigment cells

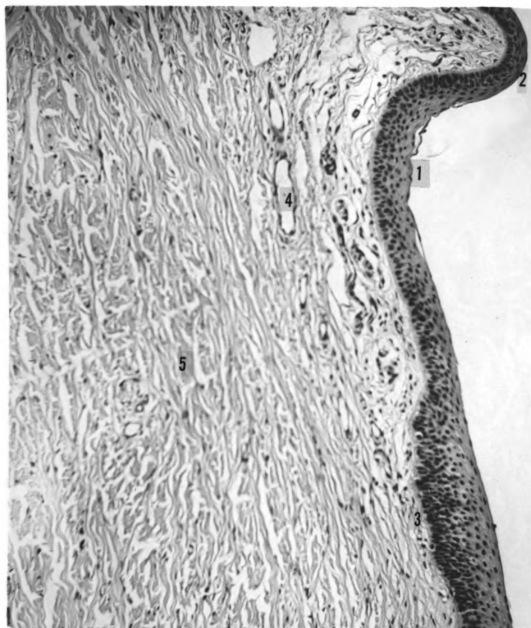


PLATE XXVII

Bulbar and limbal conjunctivae of the goat

Vertical section, H. and E. Stain, 257X

(1) Bulbar conjunctiva, (2) Conjunctival fold, (3) Limbal conjunctival epithelial thickening (4) Vein, (5) Sclera

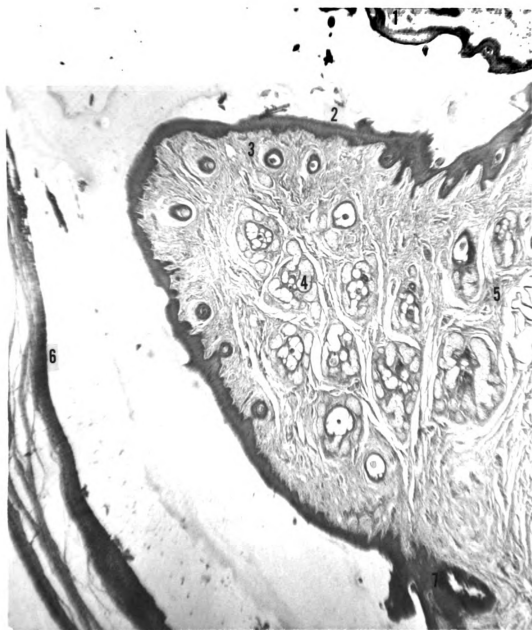


PLATE XXVIII

Lacrimal caruncle of sheep

Longitudinal section, PAS reagent, 44X

(1) Upper eyelid, (2) Stratified squamous epithelium (caruncular conjunctiva), (3) Hair, (4) Sebaceous gland, (5) Sweat gland, (6) Membrana nictitans, (7) Goblet cells

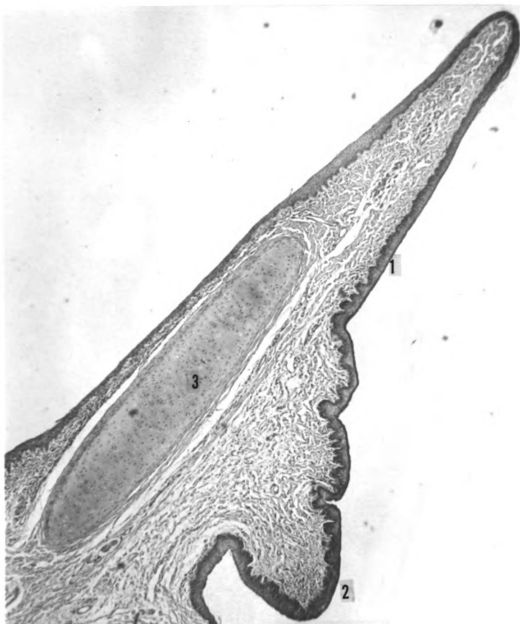


PLATE XXIX

Membrana nictitans of sheep

Longitudinal section, H. and E. Stain, 68X

- (1) Stratified squamous conjunctival epithelium with rete pegs,
(2) Fold on outer surface, (3) Nictitans hyaline cartilage covered
with perichondrium

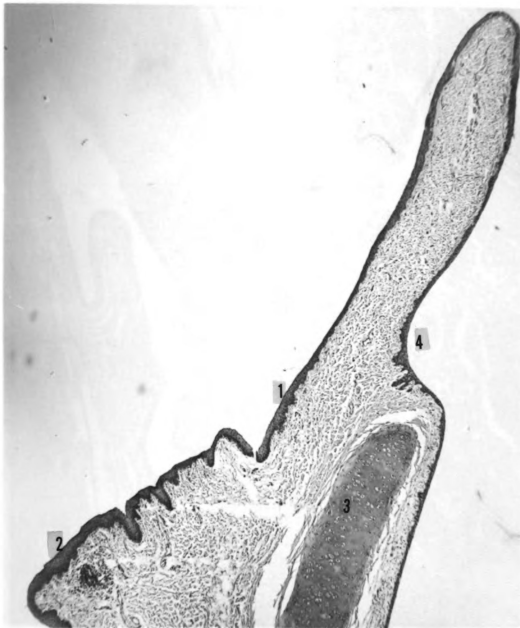


PLATE XXX

Membrana nictitans of the goat

Longitudinal section, H. and E. Stain, 49X

(1) Stratified squamous epithelium with rete pegs, (2) Fold on outer surface, (3) Nictitans hyaline cartilage covered with perichondrium, (4) Groove on ventral surface

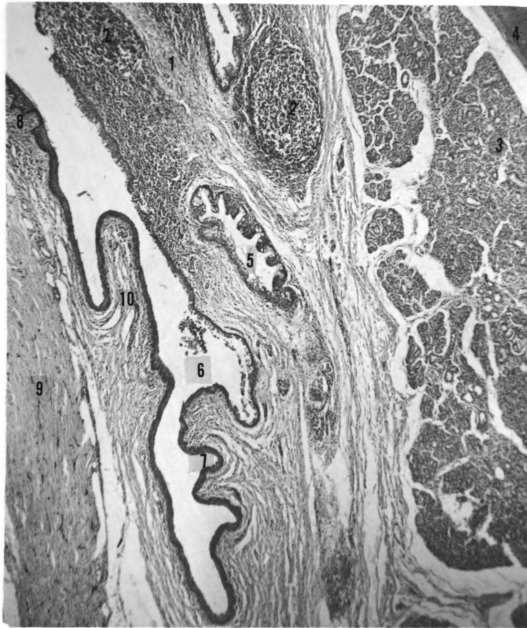


PLATE XXXI

Nictitans gland and fornix conjunctiva of sheep

Vertical section, H. and E. Stain, 68X

(1) Nictitans conjunctival fold, (2) Lymph nodules, (3) Nictitans gland, (4) Nictitans hyaline cartilage, (5) Nictitans excretory duct lined with stratified columnar epithelium containing many goblet cells, (6) Deep nictitans fornix, (7) Conjunctival folds, (8) Limbal conjunctival rete pegs, (9) Sclera, (10) Bulbar conjunctival fold

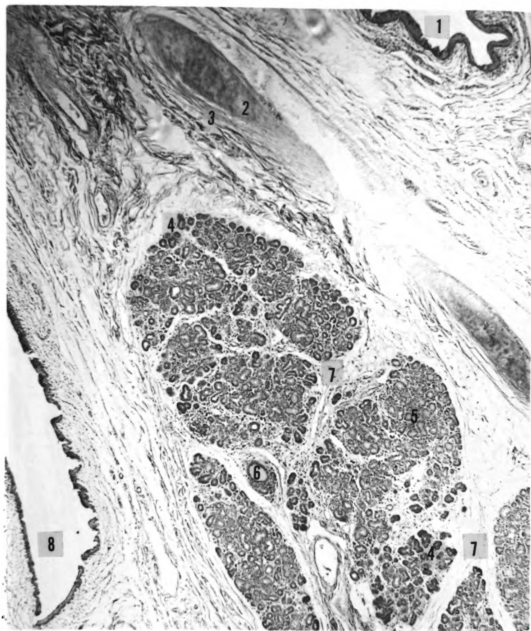


PLATE XXXII

Nictitans gland of sheep

Longitudinal section, Alcian Blue Stain, 49X

(1) Superficial fornix, (2) Nictitans hyaline cartilage, (3) Perichondrium, (4) Mucous alveoli, (5) Serous alveoli, (6) Interlobular duct, (7) Trabeculae, (8) Deep fornix

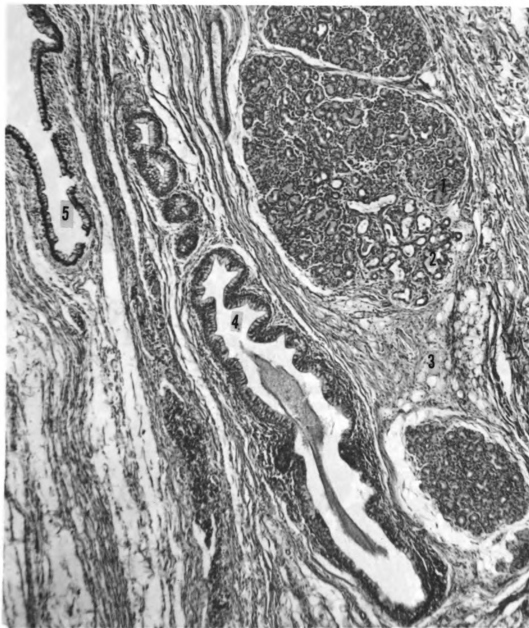


PLATE XXXIII

Nictitans gland with excretory duct of sheep

Longitudinal section, H. and E. Stain, 74X

(1) Serous alveoli, (2) Mucous alveoli, (3) Interlobular fat,
(4) Excretory duct lined with stratified columnar epithelium con-
taining many goblet cells, (5) Deep nictitans fornix

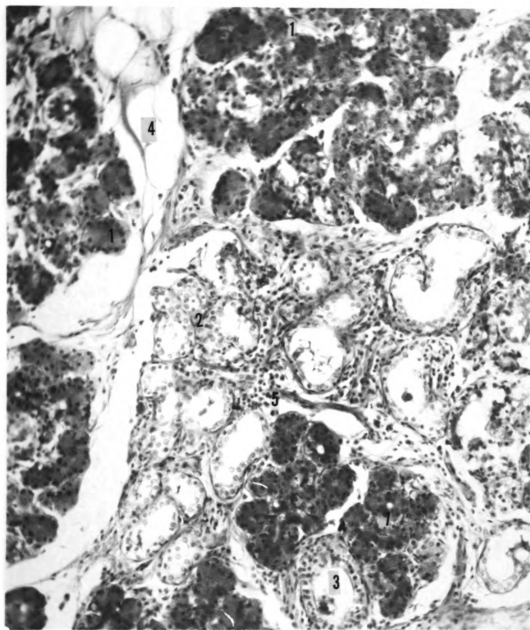


PLATE XXXIV

Nictitans gland of sheep

Vertical section, PAS reagent, 236X

(1) Mucous alveoli, (2) Serous alveoli, (3) Duct with PAS positive luminal content, (4) Interlobular fat cells in trabecula, (5) Plasma cells

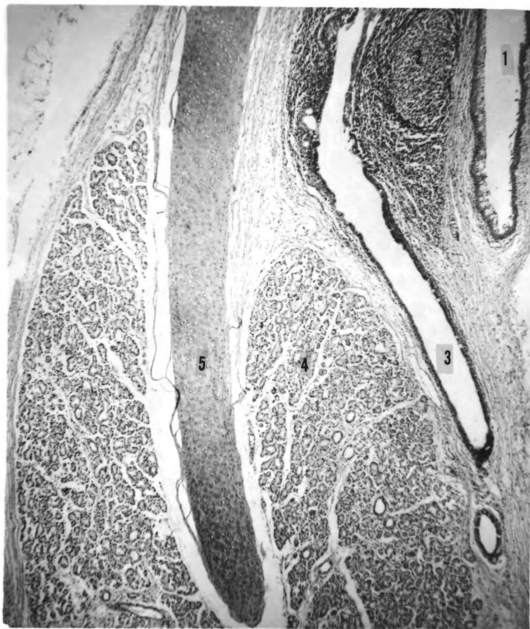


PLATE XXXV

Nictitans gland with excretory duct of the goat
Longitudinal section, H. and E. Stain, 57X

(1) Deep nictitans fornix, (2) Lymph nodule, (3) Excretory duct,
(4) Nictitans gland, (5) Nictitans hyaline cartilage covered by
perichondrium

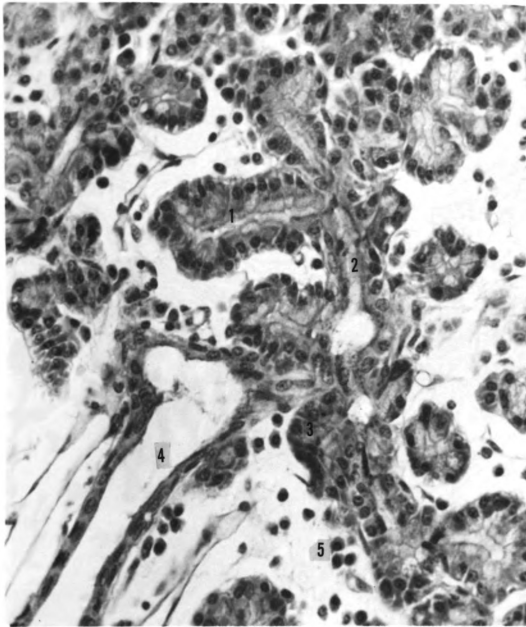


PLATE XXXVI

Nictitans gland of the goat

Vertical section, PAS reagent, 720X

(1) Seromucous mixed alveolus, (2) interalveolar tube, (3) PAS positive alveolus, (4) Alveolar duct, (5) Interalveolar plasma cells

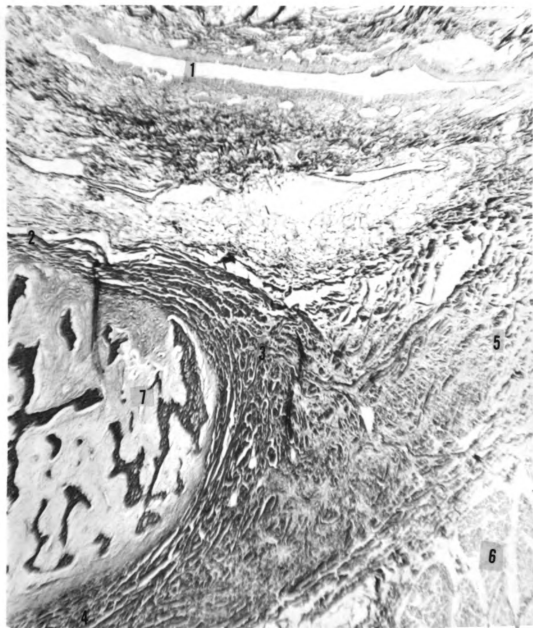


PLATE XXXVII

Periorbital and orbital septum of sheep

Vertical section, Weigert and Van Gieson's Stain, 46X

(1) Lacrimal sac, (2) Periorbital (orbital periosteum), (3) Arcus marginale, (4) Periosteum, (5) Orbital septum, (6) Orbicularis oculi, (7) Bony orbital margin

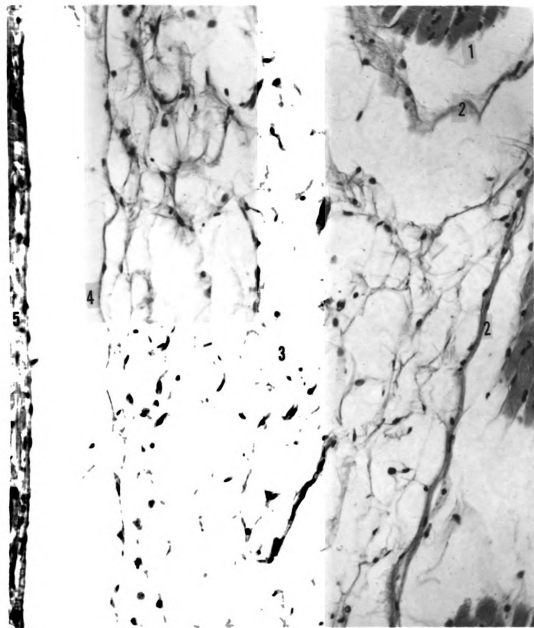


PLATE XXXVIII

Bulbar fascia (Tenon's capsule) of sheep
Vertical section, H. and E. Stain, 250X

(1) Extrinsic ocular muscle, (2) Muscular fascia, (3) Orbital fat,
(4) Bulbar fascia, (5) Sclera

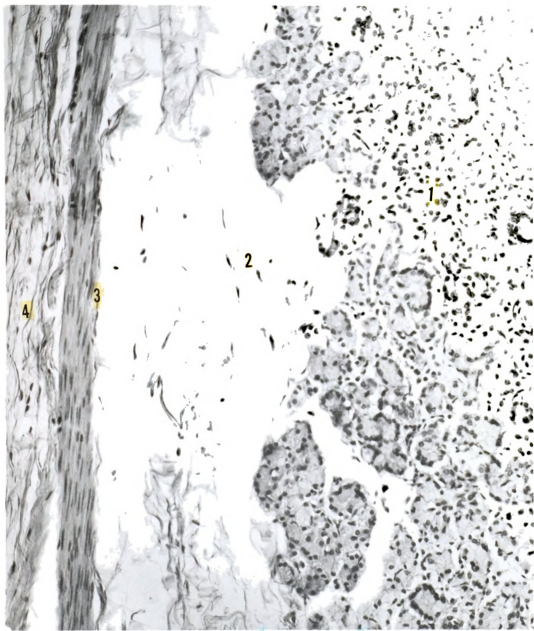


PLATE XXXIX

Lacrimal gland and smooth muscle of sheep

Vertical section, H. and E. Stain, 295X

(1) Lacrimal gland, (2) Loose areolar tissue (capsule), (3) Smooth muscle, (4) Muscular sheath

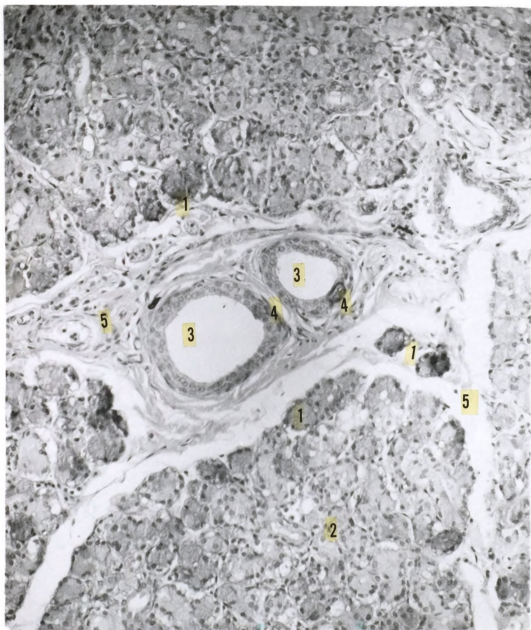


PLATE XL

Lacrimal gland of sheep

Cross section, Alcian Blue Stain, 275X

- (1) Mucous (Alcian blue positive) alveoli, (2) Serous alveoli,
(3) Interlobular duct lined with stratified cuboidal epithelium,
(4) Goblet cells, (5) Trabeculae

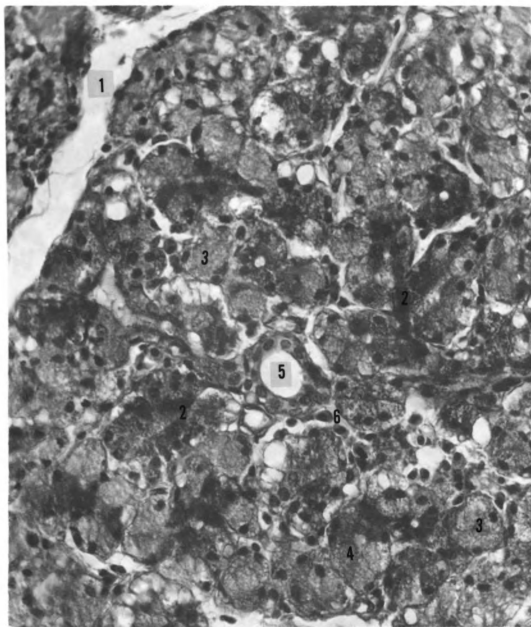


PLATE XLI

Lacrimal gland of sheep

Vertical section, PAS reagent, 684X

(1) Trabecula, (2) Mucous (PAS positive) alveoli, (3) Serous alveoli, (4) Mixed (seromucous) alveoli, (5) Interalveolar duct, (6) Interalveolar plasma cells



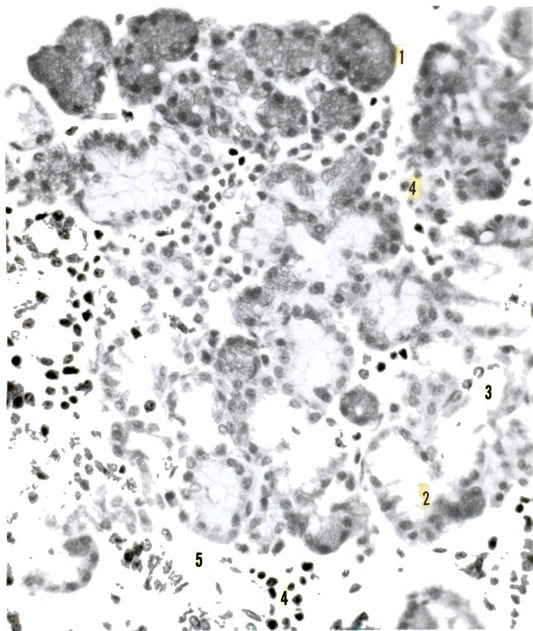


PLATE XLII

Lacrimal gland of the goat

Vertical section, PAS reagent, 646X

(1) Mucous (PAS positive) alveoli, (2) Seromucous (mixed) alveoli, (3) PAS negative duct epithelium, (4) Plasma cells, (5) Vein



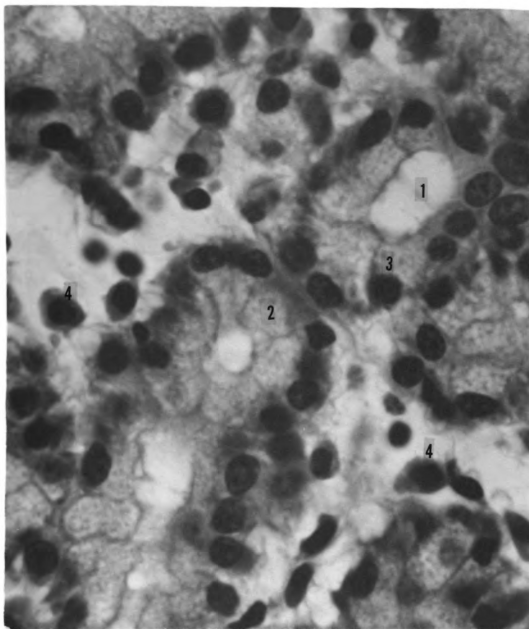


PLATE XLIII

Lacrimal gland of the goat

Vertical section, H. and E. Stain, 1704X

(1) Alveolar lumen, (2) Pyramidal glandular cell, (3) Spherical nucleus, (4) Plasma cells

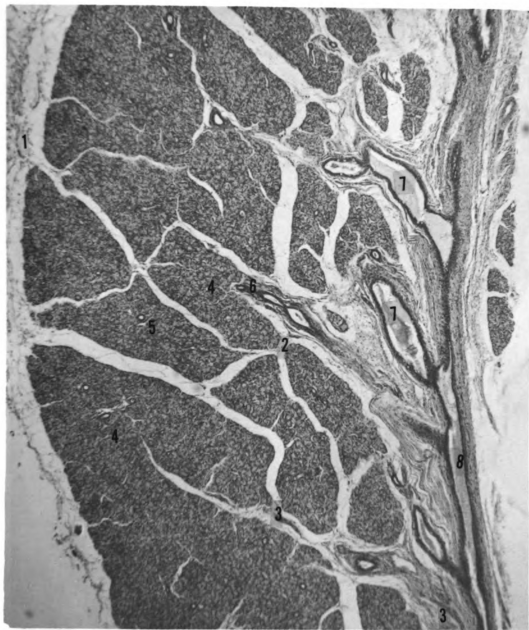


PLATE XLIV

Lacrimal excretory duct origin in sheep

Vertical section, H. and E. Stain, 48X

- (1) Capsule, (2) Trabeculae, (3) Smooth muscle fibers, (4) Lobules,
(5) Intralobular duct, (6) Lobular duct, (7) Interlobular duct,
(8) Excretory duct

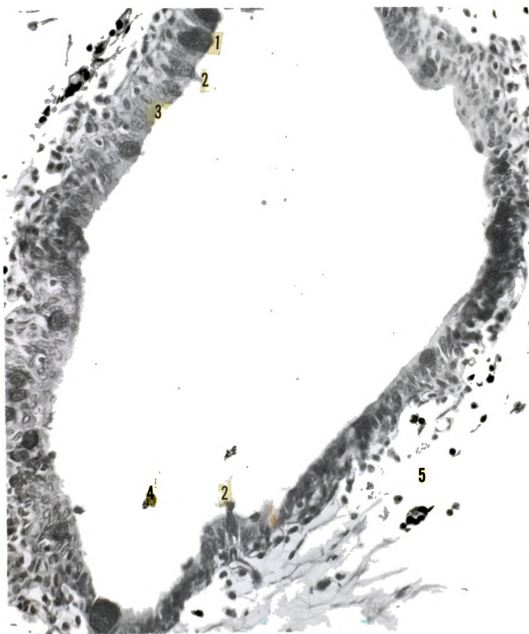


PLATE XLV

Lacrimal excretory duct of sheep

Transverse section, PAS reagent, 394X

- (1) Goblet cells (PAS positive), (2) Apical projection of goblet cells,
(3) Stratified columnar epithelium, (4) PAS positive luminal content,
(5) Substantia propria

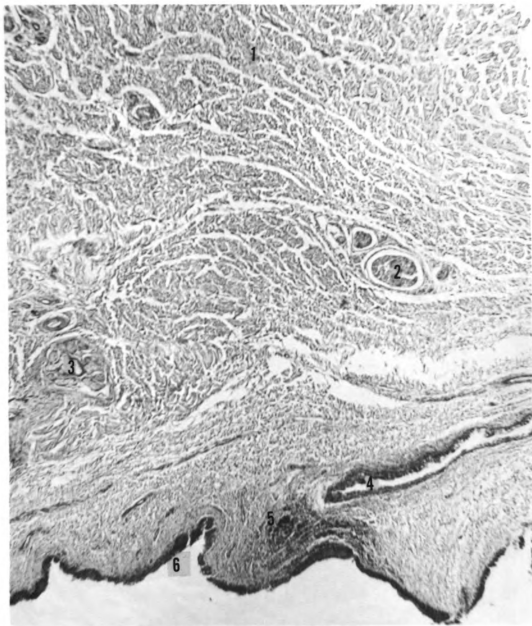


PLATE XLVI

Lacrimal excretory duct of sheep

Vertical section, H. and E. Stain, 51X

- (1) Upper eyelid, (2) Smooth muscle bundle, (3) Tarsal gland,
(4) Excretory duct, (5) Lymph nodule, (6) Post-tarsal conjunctiva

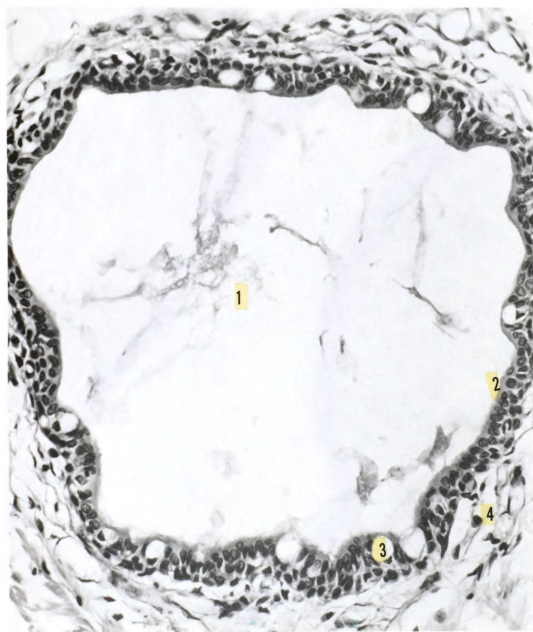


PLATE XLVII

Lacrimal excretory duct of the goat

Cross section, H. and E. Stain, 525X

(1) Luminal content, (2) Stratified cuboidal epithelium, (3) Goblet cell, (4) Substantia propria



PLATE XLVIII

Lacrimal canaliculi of sheep

Vertical section, H. and E. Stain, 278X

(1) Stratified squamous epithelium, (2) Substantia propria,
(3) Vein



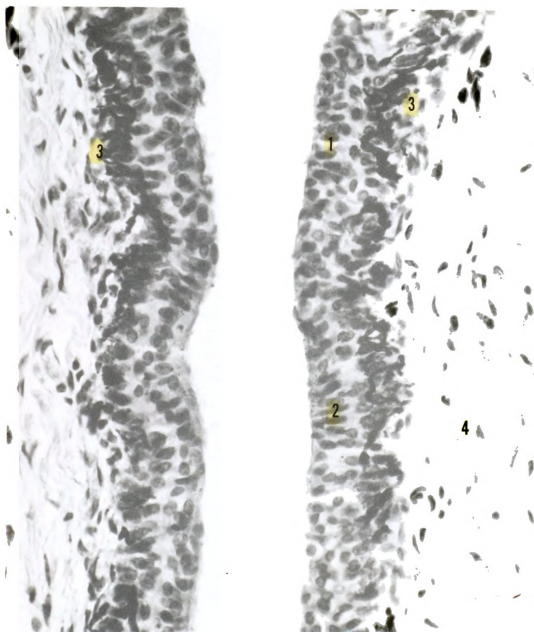


PLATE XLIX

Lacrimal sac of sheep

Vertical section, H. and E. Stain, 600X

(1) Stratified columnar epithelium, (2) Columnar cell extending towards base, (3) Connective tissue pigment cells, (4) Substantia propria

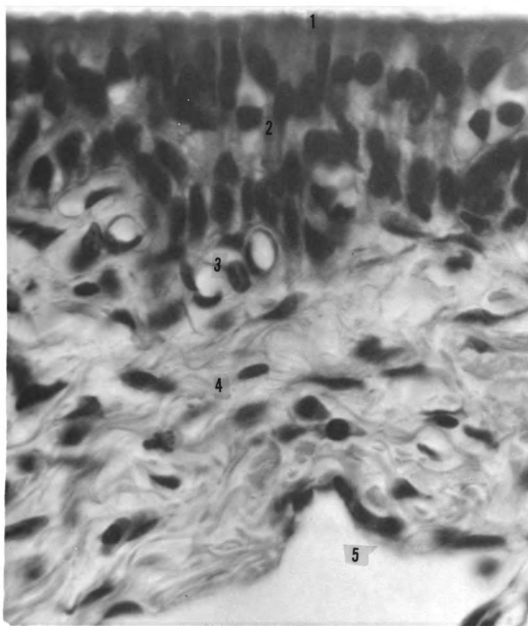


PLATE L

Lacrimal sac of sheep

Vertical section, H. and E. Stain, 1065X

(1) Stratified columnar epithelium, (2) Columnar cell extending towards base, (3) Capillaries, (4) Substantia propria, (5) Venous sinus

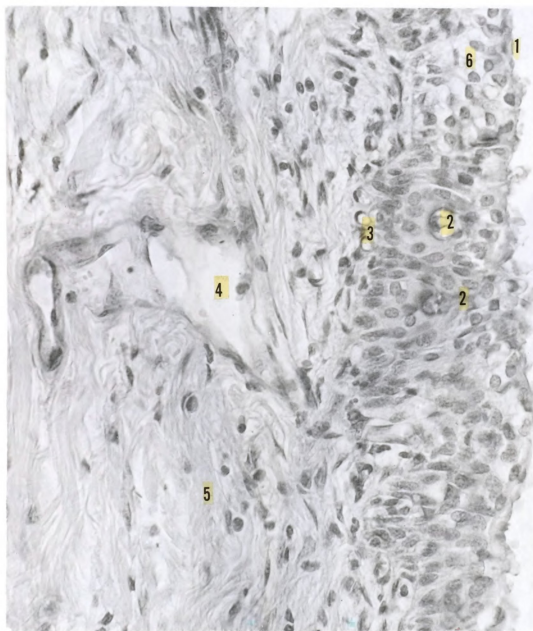


PLATE LI

Lacrimal sac of sheep

Vertical section, Alcian Blue Stain, 630X

(1) Stratified cuboidal epithelium, (2) Goblet cell, (3) Capillaries,
(4) Venous sinus, (5) Substantia propria, (6) Developing goblet cells





PLATE LII

Lacrimal sac and nasolacrimal duct of sheep

Vertical section, H. and E. Stain, 300X

(1) Lacrimal sac, (2) Nasolacrimal duct, (3) Stratified columnar epithelium, (4) Substantia propria, (5) Venous sinus

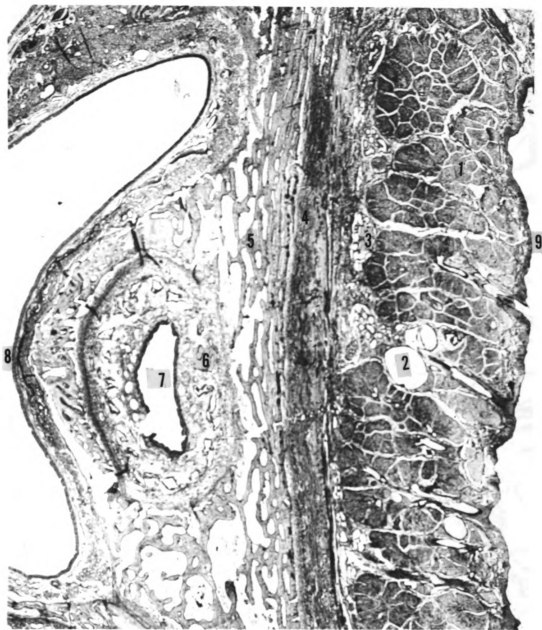


PLATE LIII

Nasolacrimal duct and lacrimal pouch gland of sheep

Vertical section, Mallory's triple stain, 220X

(1) Lacrimal pouch (modified sebaceous) gland, (2) Duct of pouch gland, (3) Sweat gland, (4) Periosteum, (5) Bone, (6) Venous plexus, (7) Nasolacrimal duct lined with stratified columnar epithelium, (8) Nasal epithelium, (9) Pouch epithelium



PLATE LIV

Nasolacrimal duct of sheep: midportion

Cross section, PAS reagent, 78X

- (1) Weakly PAS positive stratified columnar epithelium,
(2) Substantia propria, (3) Venous plexus

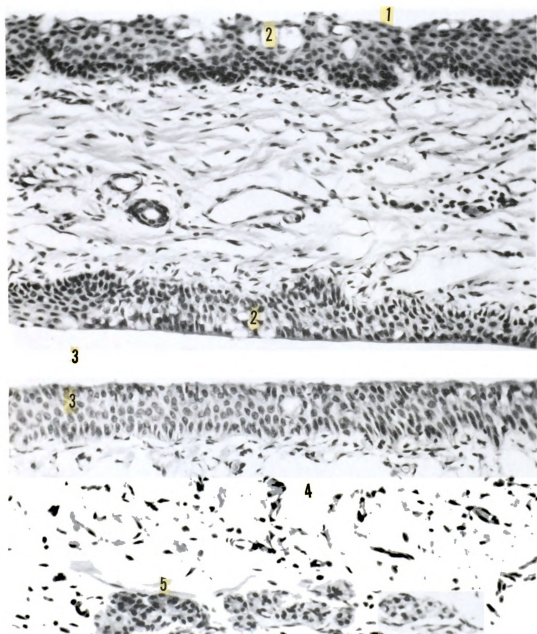


PLATE LV

Nasolacrimal duct of sheep: midportion

Vertical section, H. and E. Stain, 303X

(1) Nasal epithelium, (2) Goblet cells, (3) Nasolacrimal duct lined with stratified columnar epithelium, (4) Venous sinus, (5) Seromucous gland

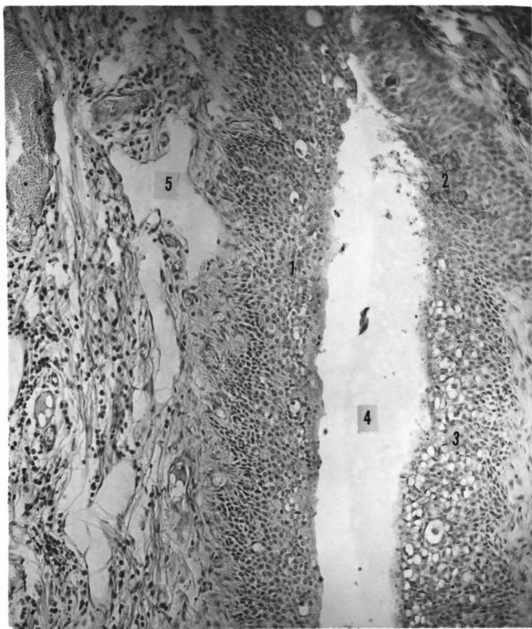


PLATE LVI

Nasolacrimal duct of sheep: Distal portion

Longitudinal section, Alcian Blue Stain, 198X

(1) Stratified cuboidal epithelium, (2) Goblet cells, (3) Intra-epithelial vacuoles, (4) Lumen of the duct, (5) Venous sinus

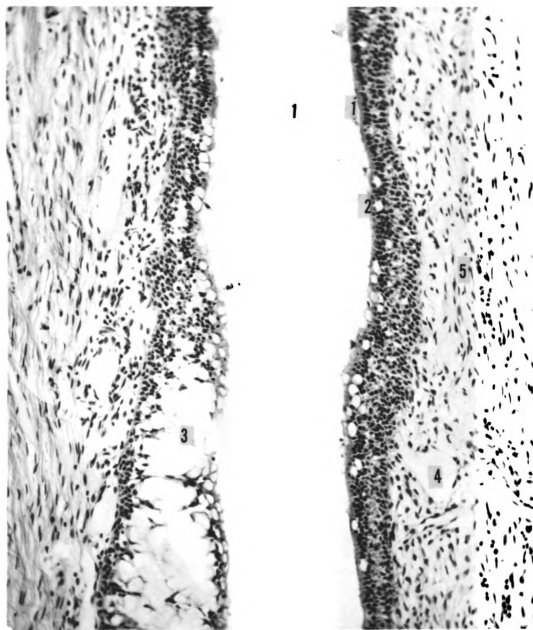


PLATE LVII

The nasolacrimal duct of the goat: proximal portion

Vertical section, H. and E. Stain, 240X

(1) Nasolacrimal duct lined with stratified columnar epithelium

(1) Stratified columnar epithelium, (2) Single goblet cells, (3) Group of goblet cells, (4) Venous sinus, (5) Substantia propria

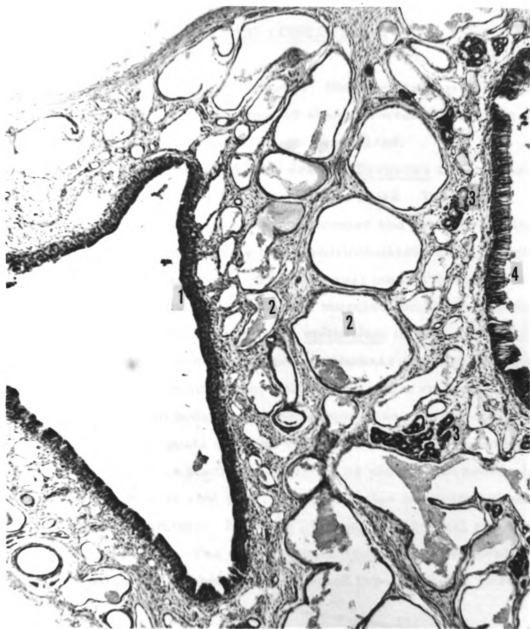


PLATE LVIII

Nasolacrimal duct of the goat: midportion

Cross section, H. and E. Stain, 76X

(1) Stratified columnar epithelium of nasolacrimal duct, (2) Venous plexus in substantia propria, (3) Seromucous gland, (4) Pseudostratified columnar nasal epithelium

SUMMARY AND CONCLUSIONS

To investigate the gross anatomy, histology and histochemistry of the eye adnexa, specimens from 20 sheep, 2 weeks to 4 years old and 4 goats, 5 days to 5 months of age, were used.

The following conclusions are drawn: Eyebrows are represented by numerous sensory and a few superciliary hairs. The medial palpebral commissure of sheep is unpigmented and grooved leading to a lacrimal pouch which contains large multilobulated sebaceous glands. Goats lack the lacrimal pouch. Smooth tarsal muscle (muscles of Müller) and marginal palpebral skeletal muscles (muscles of Riolan) are well developed. The conjunctival epithelium is very irregular being stratified squamous to cuboidal to columnar and even transitional at a few places. It contains many goblet cells and a varying number of lymphocytes. Lymph nodules are more numerous in sheep. The post-tarsal conjunctiva of goats contains epithelial "buds." The limbal conjunctiva contains no Manz glands but in its place a thickened pigmented epithelium with rete pegs. The caruncles of sheep and goats are histologically similar. The deep nictitans (Harderian) gland is absent in both species. The superficial nictitans gland is simple tubuloalveolar mixed in sheep and compound tubuloalveolar mixed in goats.

Microscopically the lacrimal glands resemble the nictitans glands. Many plasma cells are found in the nictitans and lacrimal glands of both species. Six or seven excretory lacrimal ducts are present in sheep and goats and are lined with stratified columnar epithelium having many goblet cells. Connective tissue septa of the lacrimal gland of sheep contains smooth muscle fibers. The lacrimal passage epithelium

is stratified: squamous at the puncta, cuboidal to columnar in the canaliculi and columnar with a variable number of goblet cells in the lacrimal sac and nasolacrimal duct. At a few areas pseudostratified columnar epithelium is also observed in the lacrimal sac and nasolacrimal duct. They are surrounded throughout by a rich venous plexus resembling erectile tissue. A few seromucous glands surround the lower third of the nasolacrimal duct.



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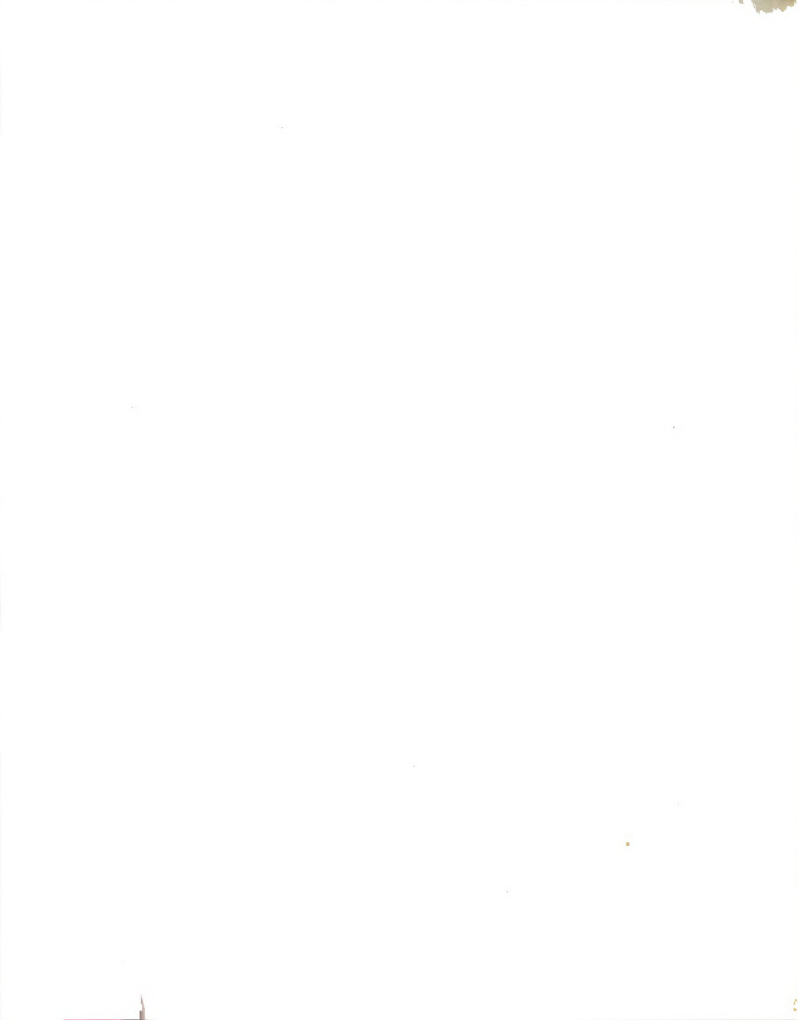
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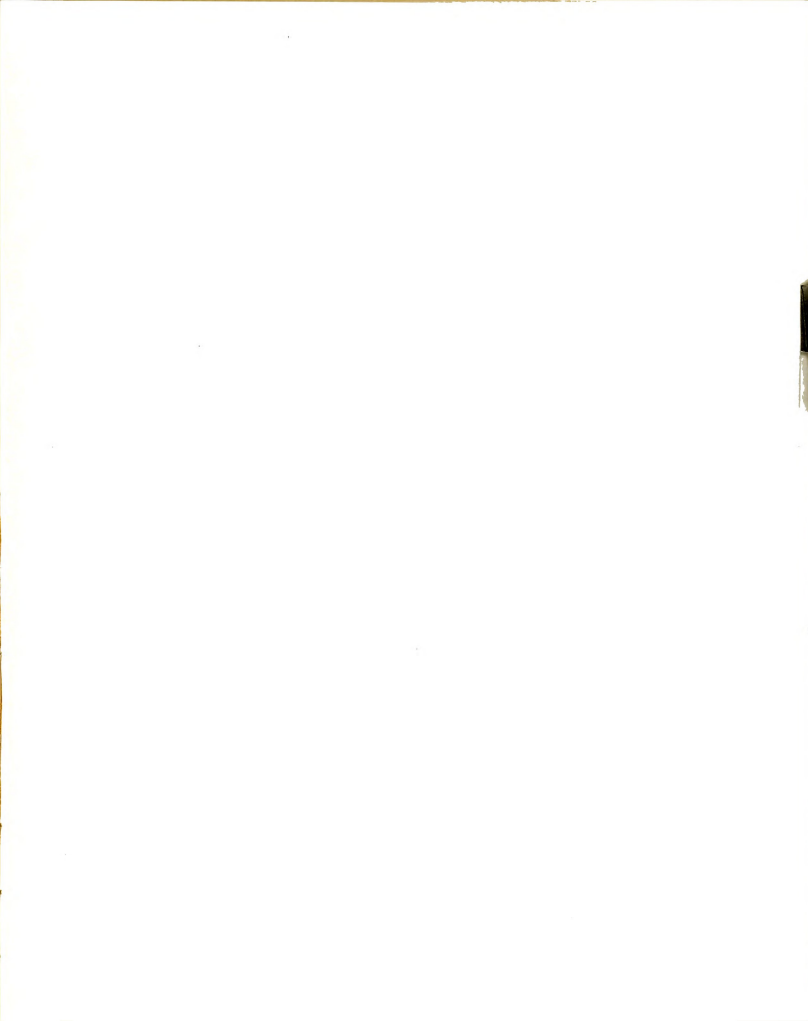
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