MORPHOLOGY AND MORPHOMETRY OF THE EYEBALL AND ITS APPENDAGES OF THE DROMEDARY CAMEL

(Camelus dromedarius)

By
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DEDICATION

To my mother Fatima and

memory of my father Ibrahim

To my husband Alkhatim

To my family

With love

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INTRODUCTION

The camel is an important animal species uniquely adapted to hot and arid environment. The dromedary camel is mainly found in the arid areas of Eastern Africa, mainly Somalia and Sudan. The majority of camels in this region are kept by migratory pastoralist (nomads). The extraordinary attributes of the camel as a riding and pack animal have already been appreciated (Schwartz and Dioli, 1992).

In Sudan, the one humped camel (*Camelus dromedarius*) is a useful animal as a source of milk, meat, hides, wool, hair as well as a draft animal and serves for riding and pack animal. Furthermore, it plays an important role in the national and foreign income.

The socioeconomic importance of the dromedary camel in the Sudan should encourage researchers to investigate its anatomy, physiology, habitat, reproduction and various other parameters.

The population of the livestock in Sudan is 128.523.000 animals (3.200.000 camels, 39.952.000 goats, 47.043.000 sheep and 38.325.000 cattle) (MARF, 2001).

The available literature on the morphology of the eyeball and its appendages of domestic mammals, including goat, sheep, ox, buffalo, pig , dog and cat was given by Symthe (1958), Prince, Diesem, Eglitis and Ruskell (1960), Diesem (1968, 1975), Dellmann (1971), Magrane (1971), Hoffmann (1972), Das (1979), Prasad and Sinha (1979), Dellmann and Brown (1981), Peiffer, DeVanzo and Cohen (1981), Kuwabara (1983), Lavach (1990), Gellatt (1991), Slatter (2001) and Ollivier, Samuelson, Brooks, Lewis, Kallerg and Kamaroy (2004).

Several studies were undertaken to study the gross anatomy of the eyeball and its appendages in the camel (Leese, 1927; Dowling and Nay,

1962; Lee and Schmidt. Nielsen, 1962; Tayeb, 1962; Fahmy, Arnautovic and Abdalla, 1971; Kanan, 1972; Rahi, Sheikh and Morgan, 1980; Bareedy, Soliman, Balah and Omer, 1986; Sayed, 1988; Ibrahim, 1990; Abou-Elmaged, Selim, Ali, Mustafa, Kelany and Sayed, 1990; Fateh el Bab, Kamel, Selim and Sayed, 1991; Nagpal, Singh, Dhingra and Singh, 1991; Abou-Elmaged, 1992; Hifny and Aly, 2006; Hifny, Aly and Abdalla, 2006; Kotb, 2006; Zayed, 2006).

The eye of the camel is a highly specialized sense organ in the body. The eyeball is composed of three tunics: the outer fibrous tunic which is subdivided into the sclera and cornea; the middle vascular tunic which consists of the choroid, ciliary body and iris; and inner nervous tunic which consists only of the retina.

The appendages of the eyeball of the camel include the two eyelids upper and lower, conjunctiva, lacrimal apparatus, third eyelid and superficial and deep glands of the third eyelid. The presence of the superficial gland of the third eyelid of the camel has been reported for the first time by Fahmy ***et al.*** (1971).

The morphology, histochemistry and morphometry of the lacrimal apparatus of the camel is extensively investigated by Ibrahim (2003).

The ultrastructure of the deep gland of the third eyelid in the camel is briefly studied by Abou-Elmaged ***et al.*** (1990) and Abou-Elmaged (1992). Investigations dealing with the ultrastructure of the third eyelid and superficial gland of the third eyelid of the camel appear to be lacking.

A few morphometerical investigations have been done on the deep gland of the third eyelid of the camel (Fateh el Bab ***et al.***, 1991).

The current study was therefore undertaken to provide a better knowledge and understanding of the gross anatomy, histology, ultrastructure and morphometry of the eyeball and its appendages of the dromedary camel.

CHAPTER ONE

LITERATURE REVIEW

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I.1. Gross Anatomy

I.1.1. Position and Topography of the Eyeball

The eyeball of most domestic mammals is lodged almost wholly within a bony chamber known as the orbit which is surrounded by the orbital muscles and periorbita (Symthe, 1958; Dellmann and Brown, 1981; Cormack, 2001).

Dyce, Sack and Wensing (1987) stated that it is situated laterally in the horse, ruminants and rabbits, and well forward in the dog and cat.

In the horse, the eyeball is situated in the rostral part of the orbital cavity (Bradley, 1947; Diesem, 1975).

In human, Symthe (1958) described that a little more than half of the eyeball is located within the orbital rim and the eyelids are large, motile and cover the greater part of the orbital portion.

In the camel, Tayeb (1962) and Ibrahim (1990) reported that the eyeball is totally directed towards the lateral side of the orbit.

I.1.2. Weight and Dimensions of the Eyeball

The weight and dimensions of the eyeball and cornea vary with the animal species, size and age.

In the horse, the eyeball weighs about 45 – 60 grams, and measures 5.5 cm. in circumference, 5.0 cm. in length and 4.5 cm. in width, while

the cornea is about 2.5 cm. long and 3.0 cm. wide (Bradley, 1947; Diesem, 1975; Martin and Anderson, 1981; Lavach, 1990; Barnett, Crispin, Lavach, and Matthews, 1995).

In the ox, Symthe (1958) reported that the eyeball measures about 4.3 cm. in circumference, 4.2 cm. in length and 3.7 cm. in width, while the cornea is about 2.5 cm. long and 3.0 cm. wide (Diesem, 1975).

In small ruminants (Symthe, 1958), the eyeball measures about 3.4 cm. in circumference, 3.3 cm. in length and 3.1 cm. in width.

In the dog (Bradley, 1948; Diesem, 1975), the eyeball weighs about 4 – 8 grams and measures about 4.2 cm. in circumference, 3.4 cm. in length and 3.7 cm. in width.

In the cat (Symthe, 1958; Diesem, 1975), the circumference, length and width of the eyeball are about 2.2 cm. 2.3 cm. and 2.6 cm. respectively.

In the pig the eyeball is about 2.2 cm. in circumference, 2.2 cm. in length and 2.5 cm. in width (Diesem, 1975).

In human (Symthe, 1958) the eyeball is about 2.3 cm. circumference, 2.3 cm. long and 2.4 cm. wide.

The measurements of the weight and dimensions of the eyeball of the camel is given by Symthe (1958) and Rahi ***et al.*** (1980) Symthe (1958) reported that the eyeball of the camel is about 4.7 cm. in circumference, 4.5 cm. long and 4.0 cm. wide, whereas Rahi ***et al.*** (1980) reported that the eyeball is about 3.5 cm. in length and 3.1 cm. in width and the cornea is about 2.5 cm. long and 1.7 cm. wide.

I.1.3. The Eyelids and Conjunctiva

There are two eyelids; upper and lower eyelids. They are situated in front of the eyeball. The two eyelids are joined to form the medial and lateral angles or canthi. The superficial surface of the eyelid is covered by

skin and the deep surface is covered with conjunctiva, a sheet of mucous membrane (Bradley, 1947; Diesem, 1968; Diesem, 1975; Snell, 2000b).

In the horse, the eyelids are thin and the upper lid is more extensive than the lower lid (Bradley, 1947; Prince ***et al.***, 1960; Diesem, 1968).

In the ox and cat, the eyelids are quite thick and the upper eyelid of the cat is devoid of palpebral conjunctiva (Diesem, 1968; Diesem, 1975).

In the buffalo, the eyelids are convex, greatly bulged outward and the upper eyelid is greatly motile (Ibrahim, 1990).

In the pig, the eyelids are thick and a considerable amount of adipose tissue is found under the skin and conjunctiva (Diesem, 1975).

In the camel, the two eyelids are thick, large, and prominent laterally, and the lower lid moves freely, as compared with that of other domestic animals (Tayeb, 1962). Ibrahim (1990) recorded that the free border is pigmented.

In most domestic mammals, the conjunctiva lines the lower, upper and the third eyelids and then is reflected onto the eye at the corneoscleral junction (Diesem, 1975; Dyce ***et al***., 1987).

In the horse, the conjunctiva is smooth, pink in colour (Dyce and Wensing, 1971), and contained isolated nodules of lymphatic tissue (Diesem, 1975). In the donkey and buffalo, the conjunctiva is transparent and bright rosey red in colour (Ibrahim, 1990).

In the camel, the conjunctiva is pink in colour and contained subconjunctival lymph nodules (Ibrahim, 1990) and is folded in a peculiar fashion, known as the lacrimal recess of the conjunctiva (Tayeb, 1962).

I.1.4. The Eyelashes

In all mammals, the eyelids have hairs associated with their margins, known as eyelashes or cilia (Symthe, 1958; Diesem, 1975).

The number of the eyelashes varies within the species. In the horse, the eyelashes are numerous, long, strong, and deeply rooted in the lateral angle of the upper lid (Talukdar, Calhoun and Stinson, 1972b). The eyelashes are arranged in four rows (Bradley, 1947, Symthe, 1958; Diesem, 1968, Talukdar ***et al.***, 1972b) in the upper lid, but they are either few, short and weak (Diesem, 1975) or completely absent on the lower lid (Prince ***et al.***, 1960).

In the ox, the eyelashes of the upper lid are large, densely arranged (Dyce and Wensing, 1971) and about 100 in number (Diesem, 1968), but they are few and short in the lower lid (Diesem, 1968; Diesem, 1975).

In the dog and pig, the eyelashes are numerous and long on the upper lid and they are absent on the lower lid (Prince ***et al.***, 1960).

In the cat, there are a few eyelashes on each eyelid (Symthe, 1958; Diesem, 1975).

In the camel, Tayeb (1962) and Ibrahim (1990) stated that the eyelashes are long, strong and densely arranged. Moreover, there are groups of long and peculiar hairs at the anterior surface of the upper lid dorsal to the medial canthus.

I.1.5. The Third Eyelid

The third eyelid of mammals is also referred to as the nictitating membrane or palpebra tertia (Dyce and Wensing, 1971; Diesem, 1975; Dyce ***et al***., 1987). It is situated at the medial angle of the eye of the horse (Bradley, 1947), domestic birds (Fuijoka, 1963; Mclelland, 1975), ox (Dyce and Wensing, 1971), sheep, goat, pig, cat (Diesem, 1975), donkey (Ibrahim, 1990), dog (Constantinescu and McClure, 1990), buffalo (Ibrahim, 1990; Abou-Elmaged, 1997), and rabbit (Render, 2001).

The third eyelid is supported by a curved plate of cartilage in the horse (Bradley, 1947; Diesem, 1975) and rabbit (Render, 2001), T-shaped plate of cartilage in the ox and small ruminants (Diesem, 1975) and the

dog (Bradley, 1948; Constantinescu and McClure, 1990), angled cartilage in the ox (Dyce and Wensing, 1971) and an anchor shaped of cartilage in the pig (Diesem, 1975). In domestic birds, the third eyelid is devoid of cartilage (Fuijoka, 1963; Mclelland, 1975)

Diesem (1975) reported that the third eyelid of mammals is covered by a fold of conjunctiva, and its free border is pigmented and highly vascularized.

In the camel, the nictitating membrane is thin, large, triangular in outline and well developed, projecting over the medial canthus and pigmented at its free border (Tayeb, 1962; Fahmy ***et al.***, 1971; Ibrahim, 1990; Nagpal ***et al.*** l, 1991; Hifny and Aly, 2006). Fahmy ***et al.*** (1971) stated that the cartilage of the palpebra tertia of the camel is comma shaped, whereas Nagapal ***et al***. (1991) reported that the cartilage is T-shaped.

I.1.6. The Glands of the Third Eyelid

Diesem (1975) reported that there are two glands associated with the nictitating membrane; Harderian and nictitatan glands.

In the horse, the Harderian gland is small, diffuse structure and it contains reddish-yellow granules (Symthe, 1958), and has a structural resemblance to the lacrimal gland (Bradley, 1947).

In the donkey, the Harderian gland is represented by bright brown masses of small sized lobes of glandular tissue (Ibrahim, 1990).

In the ox, the Harderian gland is large (Symthe, 1958; Dyce and Wensing, 1971), and is subdivided into two parts (Diesem, 1975) whereas in the buffalo, Ibrahim (1990) and Abou-Elmaged (1997) described a well developed Harderian gland. However, Das (1979) denied the presence of this gland in this species.

Symthe (1958) stated that the Harderian gland is large in sheep and goat, while Diesem (1975) is of the opinion that the Harderian gland is absent and the nictitatan gland is large.

In the dog, the Harderian gland is a diffuse structure and pinkish in colour (Symthe, 1958) or reddish (Bradley, 1948) and resembles the lacrimal gland (Martin, Munnell and Kaswan, 1988).

The pig is one of a few species which have both a deep Harderian gland and a superficial nictitatan gland, and the Harderian gland is quite large when compared with that of other domestic mammals (Diesem, 1975).

In the rabbit (Render, 2001) the Harderian gland is located antero-ventral to the eyeball and it is small and pink in colour.

In domestic birds (Fuijoka,1963; Mclelland,1975) the Harderian gland is well developed and large.

In human and monkey (Symthe,1958), the Harderian gland is absent.

The glands of the nictitating membrane of the camel have been studied by Fahmy ***et al.*** (1971), Sayed (1988), Ibrahim (1990) Fateh el Bab ***et al.*** (1991), Nagpal ***et al.*** (1991) and Hifny and Aly (2006).

Fahmy ***et al.*** (1971), Fateh el Bab ***et al.*** (1991) and Hifny and Aly (2006) reported that there are two glands associated with the nictitating membrane of the camel; the superficial and deep glands. Fahmy ***et al.*** (1971) stated that the superficial gland is situated in the lower part of the medial side of the third eyelid and is triangular in outline and grayish pink in colour, while the deep gland is compact, oval in outline and reddish in colour.

I.2. Histology

The histology of the eyeball and its appendages of many mammals, including man, has been reported by Trautmann and Fiebiger (1957), Symthe (1958), Ehlers (1970), Shively and Epling (1970), Dellmann (1971), Diesem (1975), Dellmann and Brown (1981), Martin and Anderson (1981), Kuwabara (1983), Banks (1993), McMinn (1994), Barnett ***et al.*** (1995), Eighth, Bran and Tripathi (1997), Junqueira, Carneiro and Kelly (1998), Bacha and Bacha (2000), Cormack (2001), Slatter (2001), Fawcett and Jensh (2002) and Ollivier ***et al.*** (2004).

I.2.A. The Eyeball

The wall of the eyeball in mammals is composed of three main coats: an outer fibrous, middle vascular and nervous coats (Dellmann and Brown, 1981; Dyce ***et al.***, 1987; Junqueira ***et al.***, 1998; Slatter, 2001).

I.2.A.1. The Fibrous Coat

In mammals, the fibrous coat is composed mainly of an elastic fibrous layer which is subdivided into an opaque white region referred to as the sclera and a circular transparent window, the cornea (Trautmann and Fiebiger, 1957; Cormack, 2001).

I.2.A.1.A. The Sclera

The sclera of mammals is composed of bundles of collagen and elastic fibers and fibroblasts (Trautmann and Fiebiger, 1957; McMinn, 1994).

Dellmann and Brown (1981) and Banks (1993) named the layer of the sclera adjacent to the choroid as *lamina fusca sclerae*, in which the elastic fibers and pigmented cells predominate.

In the camel, there are two layers which constitute the scleral envelope; the sclera proper and the lamina fusca (Rahi ***et al.***, 1980) . The sclera proper is composed of bundles of collagenous fibers, some elastic fibers and fixed cells. In the lamina fusca, the bundles of fibers become smaller and there is an increase in the number of elastic fibers. The sclera also contains focal collections of melanocytes. The episclera consists of collagenous and elastic fibers and small vascular channels (Rahi ***et al.***, 1980). Moreover, Hifny, Aly and Abdalla (2006) reported the biometrical studies of the sclera.

I.2.A.1.B. The Cornea

In most mammals, the cornea is composed of five layers: the corneal epithelium, Bowman's membrane, corneal stroma, Descemet's membrane and corneal endothelium (Symthe, 1958; Diesem, 1975; McMinn, 1994; Barnett ***et al.***, 1995). However, Slatter (2001) subdivided the cornea into the pericorneal tear film, epithelium and its basement membrane, stroma, Descemet's membrane and endothelium.

The corneal epithelium of mammals is stratified squamous nonkeratinized epithelium (Ehlers, 1970; Dellmann and Brown, 1981; Gelatt, 1991; Barnett ***et al.***, 1995; Eighth ***et al.***, 1997). Ehlers (1970), reported that the number of the epithelial layers varies with the species; in bovine the cell layers ranged between 10-15 layers, in the dog between 8-10 layers, in the pig between 6-9 layers, in the cat between 6-8 layers, in the rabbit between 5-7 layers and in the rat between 4-6 layers.

Ehlers (1970), Shively and Epling (1970), Gelatt (1991) and Banks (1993) subdivided the cells of the epithelium into three layers: basal, intermediate and superficial layers.

Bowman's membrane is also referred to as the anterior limiting membrane and is composed of a dense network of thin fibrils of collagen (Kuwabara, 1983; Banks, 1993; Cormack, 2001). The membrane is absent in mice (Whitear, 1960), dog (Shively and Epling, 1970) and pig (Diesem, 1975).

The corneal stroma is made up of numerous flat interstitial layers which contain collagen fibrils, and fibroblast (Dellmann and Brown, 1981; Junqueira ***et al.***., 1998). Dellmann and Brown (1981) and Fawcett and Jensh (2002) added that the fibers are parallel to the corneal surface within one layer, but cross each other at right angle in the successive layers.

The Descemet's membrane which is also referred to as the posterior limiting membrane is a highly thick, glassy, and homogenous basement membrane and is related to the elastic tissue (Dellmann and Brown, 1981; Banks, 1993; Eighth ***et al.***, 1997).

In mammals (Banks, 1993; Eighth ***et al.***, 1997; Junqueira ***et al.***, 1998), the corneal endothelium covers the caudal surface of the cornea and it consists of a single layer of flat hexagonal cells with their nuclei lying parallel to the Descemet's membrane.

At the corneoscleral junction, in most mammals, there is a slight rostral overlapping of the sclera over the cornea, where the corneal endothelium is changed to the conjunctival epithelium. The Descemet's membrane is continued with the connective tissue of the corneoscleral trabeculae and the corneal endothelium becomes more flat and large (Dellmann and Brown, 1981; Fawcett and Jensh, 2002).

In the camel, the cornea is subdivided into the cornea proper and limbus (Rahi ***et al.***, 1980; Bareedy ***et al.***, 1986). The cornea proper is composed of four distinct layers; the corneal epithelium which is composed of 10-12 layers of stratified squamous epithelium, the corneal

stroma, Descemet's membrane and the corneal endothelium (Rahi ***et al.***, 1980; Bareedy ***et al.***, 1986). The corneal epithelium and corneal stroma are pigmented near the limbus and the corneal stroma is vascularized at the periphery (Rahi ***et al.***, 1980). Rahi ***et al.*** (1980) and Bareedy ***et al.*** (1986) denied the presence of Bowman's membrane in the camel cornea.

I.2.A.2. The Vascular Coat

The vascular layer of mammals is composed of three regions: the choroid, ciliary body and iris (Diesem, 1975; Dyce ***et al.***, 1987; Cormack, 2001).

I.2.A.2.A. The Choroid

In most domestic mammals, the choroid is subdivided into five layers: the suprachoroid, vessel layer, tapetum lucidum, choriocapillary and basal complex layer (Symthe, 1958; Dellmann, 1971; Martin and Anderson, 1981; Banks, 1993; McMinn, 1994; Bacha and Bacha, 2000; Slatter, 2001).

The suprachoroid layer of mammals (Banks, 1993; Fawcett and Jensh, 2002; Kotb, 2006) is composed mainly of bundles of collagen fibers and some elastic fibers which are rich in fibroblasts, macrophages, lymphocytes and plasma cells. In sheep, Troilo, Nickla and Wildsoet (2000) reported that the stroma of the suprachoroid layer contains smooth muscle fibres. Symthe (1958) and Dellmann and Brown (1981) stated that the bundles of the collagen fibers assume an oblique course towards the sclera. According to Dellmann and Brown (1981), the bundles of collagen fibres are separated by the perichoroidal lymph spaces and continue with the connective tissue of the sclera.

The vessel layer contains large arteries and veins within loose connective tissue (Dellmann, 1971; Junqueira ***et al.***, 1998; Kotb, 2006).

The tapetum lucidum is somewhat different in the different species. In the horse (Diesem, 1975; Dellmann and Brown, 1981, Ktob, 2006),

sheep (Braekevelt, 1983a, bovine (Braekevelt, 1986), and buffalo (Ktob, 2006) the tapetum lucidum is fibrous and is composed of bundles of collagen fibers and fibroblasts, whereas in the cat (Dellmann and Brown, 1981; Braekevelt, 1990; Banks, 1993) and dog (Kotb, 2006) the tapetum lucidum is cellular and is composed of flat polygonal cells arranged parallel to the retina. In the dog, the layers of cells vary between 10-12, while in the cat there are about 35 layers (Banks, 1993). Symthe (1958) and Banks (1993) reported that the choroid of the pig, and monkey is devoid of the tapetum lucidum layer and is replaced by fine fibrous reticular layers that contain some vessels. In man (Leeson and Leeson, 1970; Amenta, 1978; Junqueira ***et al.***, 1998) the tapetum lucidum is absent.

The choriocapillary layer of mammals (McMinn, 1994; Fawcett and Jensh, 2002) is composed of a dense network of capillaries.

The basal complex is also referred to as the elastic membrane or Bruch's membrane (Diesem, 1975). It appears as a homogenous layer (Wouters and DeMoor, 1979; Braekevelt, 1983a, 1983b, 1987; Ollivier ***et al.***, 2004). At the rostral part, it is composed of an elastic layer sandwiched between two basement membranes, whereas at the caudal part, the elastic fibers are absent and the two basement membranes are fused together in some mammals (Dellmann and Brown, 1981; Banks, 1993).

In the camel (Rahi ***et al.***, 1980; Bareedy ***et al.***, 1986), the choroid is heavily pigmented and is composed of four layers: the suprachoroid, vascular and choriocapillary layers and Burch's membrane. The tapetum lucidum is absent. However, Kotb (2006) reported the presence of the fibrous tapetum lucidum but it is weak.

I.2.A.2.B. The Ciliary Body

In many mammals, the ciliary body connects the choroid to the periphery of the iris. It is composed of the ciliary ring, ciliary muscle and ciliary processes (Diesem, 1975; Fawcett and Jensh, 2002).

The ciliary ring is the posterior portion of the ciliary body (Diesem, 1975; Snell, 2000), and it consists of a loose connective tissue rich in elastic fibers, capillary network (Banks, 1993) and pigmented cells (Diesem, 1975).

In mammals, the ciliary muscle is situated on the outer surface of the ciliary body and inside the sclera (Trautmann and Fiebiger, 1957). It is composed of meridional, circular and radiate fibers of smooth muscle (Dellmann and Brown, 1981). The meridional fibers extend from the ciliary ring to the base of the iris in all domestic mammals investigated (Diesem, 1975). The radiating fibers are poorly developed in domestic mammals (Banks, 1993) and absent in human (Snell, 2000b). The circular fibers surround the bulb and are parallel to the corneoscleral limbus in the horse, dog, cat and pig (Trautmann and Fiebiger, 1957) and are fewer in number in human (Snell, 2000b).

The ciliary processes of mammals are the most rostral extension of the ciliary body, at the base of the iris (Banks, 1993). They consist of a central stromal core of loose connective tissue which contains a large number of blood vessels (Diesem, 1975; Bacha and Bacha, 2000; Slatter, 2001). They are covered by two layers of cubodial epithelial cells from the retina: the pigmented epithelial layer and non-pigmented epithelial layer (Copenhaver, Kelly and Wood, 1978; Dellmann and Brown, 1981).

The zonular fibers in mammals are situated between the ciliary processes and are attached near the periphery of the lens (Dellmann, 1971; Diesem, 1975; Bacha and Bacha, 2000).

In the camel, the ciliary body is situated deep into the iris. The ciliary processes extend onto the posterior surface of the iris and merge

with the pigmented epithelium of the iris. The zonular fibers originate from the posterior half of the ciliary processes (Rahi ***et al.***, 1980).

I.2.A.2.C. The Iris

The iris of domestic mammals consists of three layers: anterior border layer, stroma and the posterior pigmented epithelium (Amenta, 1978; Banks, 1993; Bacha and Bacha, 2000).

The anterior border consists of a simple endothelium continuous with the corneal endothelium (Dellmann, 1971; Eighth ***et al.***, 1997), while the posterior pigmented epithelium of the iris is covered by a bilayerd epithelium (Amenta, 1978; Ktob, 2006).

The stroma of the iris, in many species of mammals is composed of bundles of collagenous fibres which support numerous small blood vessels. It contains branched pigmented cells (Trautmann and Fiebiger, 1957; McMinn, 1994; Bacha and Bacha, 2000; Slatter, 2001). Moreover, Diesem (1975) added that the stroma of the ox, horse and pig contains elastic fibers. In addition, Dellmann and Brown (1981) stated that each blood vessel of the stroma of the iris of mammals is surrounded by collagen fibers, fibroblasts, mast cells and histocytes. Two muscles are found in the iris of mammals: the sphincter and dilator muscles (Banks, 1993). The sphincter muscle is composed of smooth muscle fibers arranged near the pupillary margin (McMinn, 1994). In sheep, the sphincter muscle is less developed when compared to that of other domestic mammals. The dilator muscle is formed by the anterior epithelial layer of the ciliary body (Dellmann and Banks, 1981). Diesem (1975) reported that a well developed dilator muscle is found in the cat.

The iris granules are also referred to as the corpora nigra. They are in the form of small masses on the lower pupillary margin and they are cystic in formation. They are composed of a framework of pigmented cells which are a continuation of the pigmented cells of the stroma

(Dellmann and Brown, 1981; Banks, 1993). In the horse (Dellmann and Brown, 1981), they are in the form of small cysts, while in sheep and goat, they appear as large cysts (Banks, 1993). Diesem (1975) denied the presence of the iris granules in the iris of the pig and cat. Symthe (1958) observed that sheep has the largest number of iris granules as compared to other mammals and they may reach up to twenty granules.

The iris angle is a complicated meshwork, referred to as the iridial angle, filtration angle and iridocorneal angle (Banks, 1993). It is formed between the corneoscleral junction, the base of the ciliary body and the ciliary border of the iris (Diesem, 1975).

Dellmann and Brown (1981) stated that the pecinate ligament is composed of bundles of collagen fibers, fibroblasts and pigment cells surrounded by a basal lamina and flat cells. In the horse, the pecinate ligament is very strong, well developed and consists of long and broad pigmented trabeculae which from a firm, flat and dense network that encircles the eye (DeGeset, Lauwer's, Simoens and Deshaepdrijverl, 1990).

The spaces of Fontana (Banks, 1993) are composed of a core of collagenous and elastic fibers covered by basement membranes and endothelial cells. Dellmann and Brown (1981) added that the spaces of Fontana project inside the trabeculae spaces of pecinate ligament.

In the camel, Rahi ***et al.*** (1980) and Ktob (2006) reported that the iris is heavily pigmented, and is covered by a layer of pigmented cells at the anterior surface, while the superior and inferior pupillary margins are equipped with special appendages which form a series of ridges. The ridges consist of proliferated pigmented epithelium which surrounds a vascularized stroma referred to as the corpora nigra. The pecinate ligament consists of a series of strands covered by endothelium that forms the iris angle (Rahi ***et al.***, 1980; Ktob, 2006).

I.2.A.3. The Nervous Coat

The nervous coat is also referred to as the retinal coat or the retina (Banks, 1993).

Trautmann and Fiebiger (1957), Diesem (1975), Dellmann and Brown (1981), Eighth ***et al.*** (1997), Junquerira ***et al.*** (1998), Bacha and Bacha (2000), Slatter (2001) and Fawcett and Jensh (2002) agreed that the structure of the retina in many mammals is divided into ten layers. These layers from outside inwards are: pigment epithelium, the layers of rods and cones, outer limiting membrane, outer nuclear layer, outer Plexiform layer, inner nuclear layer, inner Plexiform layer, ganglion cells layer, the layer of optic nerve fibres and the inner limiting membrane. The pigment epithelium is a simple squamous or cubodial epithelium resting on a basal lamina (Dellmann and Brown, 1981). The rods and cones are long, slender cells and arranged in one layer and the rods greatly outnumber the cones (Fawcett and Jensh , 2002). In human, there are about 120 million rods and 6.5 million cones and the rods are mainly found at the periphery and the cones are densest in the central retinal areas (Snell, 1984).

In the camel, the retina is also subdivided into ten layers as in other mammals (Rahi ***et al.***, 1980).

I.2.B. Appendages of the Eyeball

The appendages of the eyeball are composed of the upper and lower eyelids, conjunctiva, the third eyelid, the glands associated with the third eyelid and the lacrimal apparatus (Diesem, 1975; Eighth ***et al***., 1997).

I.2.B.1. The Eyelids and Conjunctiva

The skin of the eyelids of mammals is covered by stratified squamous epithelium (Dellmann and Brown, 1981) and has a few papillae (Fawcett and Jensh, 2002). Symthe (1958) and Dyce and

Wensing (1971) stated that there are two layers, a layer of connective tissue and a layer of glandular tissue which is called the tarsal gland. The glandular tissue of the eyelids of mammals consists of branched sebaceous glands and sweat glands (Diesem, 1975). The tarsal glands (Banks, 1993) are modified sebaceous glands with a central duct which opens into the eyelids margin and associated with the eyelashes and there are modified sweat glands associated with hair follicles. Prince ***et al.*** (1960) stated that the tarsal glands are better developed in the upper lid than in the lower lid. Trautmann and Fiebiger (1957) Dyce ***et al.*** (1987) reported the presence of the sinus hair follicles at the base of the eyelids of domestic mammals .

The tarsal glands of the horse are partly embedded in the deep face of the upper and lower eyelids (Bradley, 1947). Moreover, Talukdar ***et al.*** (1972b) reported the presence of branched sebaceous glands and large sweat glands and the upper eyelids have smooth muscle fibres.

In the ox (Diesem, 1975), the tarsal glands are completely embedded within the tissue of the upper and lower eyelids, while Dyce and Wensing (1971) reported that there are small sebaceous glands which open into the follicles of the eyelashes.

In the buffalo, the sebaceous glands are multilobulated alveolar glands which are not related to hairs follicles and open directly on the eyelid's margin (Prasad and Sinha, 1979; Hifny, Hassan, Selim and Moustafa, 1985). Hifny ***et al.*** (1985) observed that the tactile hairs are associated with poorly developed sebaceous glands and arrector pili muscles but lack sweat glands.

(Diesem, 1975) stated that the tarsal glands of sheep and goat are poorly developed and the sebaceous glands are not associated with hair follicles and the main duct is lined with stratified squamous epithelium.

In the dog, the tarsal glands are found under the conjunctival mucosa near the margins of each eyelid and have ducts (Diesem, 1975). The tarsal glands are not so well developed and there are a few sebaceous glands associated with hairs (Bradley, 1948).

In the pig, the tarsal glands are poorly developed (Dellmann and Brown, 1981), while in the cat, the tarsal glands are well developed (Dellmann and Brown, 1981).

In the camel, the tarsal glands are found only in the upper eyelid (Fahmy ***et al.***, 1971). However, Lee and Schmidt-Nielson (1962), Ibrahim (1990) and Zayed (2006) denied the presence of these glands in this species. The tarsal glands are simple branched tubular glands which are situated at the medial part of the margin of the eyelid. The secretory parts consist of mucous tubular glands and the excretory ducts are lined with simple columnar epithelium (Fahmy ***et al.***, 1971).

The conjunctiva is a thin and transparent mucous membrane which lines the inner surface of the eyelid (Fawcett and Jensh, 2002). In ruminants and the pig (Dellmann and Brown, 1981), the conjunctiva is lined by transitional epithelium, while in the horse, dog and cat (Banks, 1993) it is lined by a pseudostratified epithelium with goblet cells.

In the camel (Ibrahim, 1990; Nagpal ***et al.***, 1991) the conjunctival epithelium is stratified squamous non-keratinized epithelium with goblet cells.

I.2.B.2. The Third Eyelid

The third eyelid is a conjunctival fold fortified by a cartilaginous plate (Diesem, 1975). The type of the cartilaginous plate is somewhat different in different species. In ruminants and the dog, the cartilage plate of the third eyelid is hyaline (Ellenberger and Baum, 1943; Bank, 1993). In the horse and pig, the cartilage plate is either hyaline (Diesem, 1975), or elastic (Ellenberger and Baum, 1943; Bank, 1993). In the cat, the third

eyelid contains elastic cartilage (Banks, 1993). In the rabbit, (Render, 2001), it is hyaline cartilage.

In the bulbar surface of the third eyelid, there are numerous lymphatic nodules in the ox, sheep, horse, dog, cat, pig (Banks, 1993) and rabbit (Render, 2001).

In mammals, the third eyelid is supported by a well developed lamina propria which is a highly vascular loose connective tissue rich in fibroblast, macrophages, mast cells and plasma cells (Dellmann and Brown, 1981). In the cat, Banks (1993) observed that the loose connective tissue contains some smooth muscles fibers.

In the camel, the type of cartilage of the third eyelid is somewhat controversial. The cartilage plate is either elastic (Fahmy et al., 1971) or hyaline (Nagpal ***et al.***, 1991). Tyeb (1962) mentioned the presence of many yellowish sebaceous follicles in the third eyelid. Furthermore, Ibrahim (1990), and Hifny and Aly (2006) reported that the third eyelid is characterized by the presence of many lymph nodules scattered subconjunctivally along the bulbar surface.

I.2.B.3. The Glands of the Third Eyelid

Ballantyne and Fourman (1971), Wight, Burns, Rothwell and Mackenzie (1971), Diesem (1975), Martin ***et al.*** (1988), Ibrahim (1990), Banks (1993), and Abou-Elmaged (1997) have studied the structure of the Harderian gland in the domestic duck, fowl, pig, cattle, dog, donkey, horse and water buffalo respectively. The gland is a compound tubular and is lined with a single layer of pyramidal or columnar secretory cells.

Previous studies of the Harderian gland suggested that its structure, in general, is similar to the lacrimal gland (Bradley, 1948, Wight ***et al.***, 1971, Diesem, 1975, Martin ***et al.***, 1988), but it has two principal features of its own: the presence of the cartilage plate that extends from the third eyelid and the conjunctival fold which covers the gland.

According to Fuijoka (1963) Wight ***et al.*** (1971) and Mclelland (1975), the Harderian gland of the domestic fowl dose not contain cartilage plate within the parenchyma of the gland and it is covered by a capsule which is composed of collagenous and elastic fibers and contains capillaries and foci of lymphocytes.

Burns and Maxwell (1979) reported that the ducts of the Harderian gland in the turkey, fowl and duck are generally lined by a single layer of epithelium, the cells of which vary from cubodial to columnar, though stratified and pseudostratified regions are found.

The Harderian gland of the camel is compound, and lobulated (Fahmy ***et al.***, 1971) and tubuloalveolar (Fateh el Bab ***et al.***, 1991). The secretory endpieces are lined with pyramidal cells and a plate of elastic cartilage is present within the parenchyma of the gland. The secretory ducts are lined with stratified columnar cells rich in melanin pigment, especially in the cells of the superficial layer (Fahmy ***et al.***, 1971) and contain many mucous secreting cells (Ibrahim, 1990).

Dellmann (1971), Diesem (1975), Das (1979), Dellmann and Brown (1981), Kuwabara (1983), Gelatt (1991), Banks (1993), Eighth ***et al.*** (1997) and Slatter (2001) denied the presence of the superficial gland in the majority of mammals. However, Diesem (1975) reported the presence of the superficial gland of the third eyelid in the pig.

In the camel, the superficial gland of the third eyelid is a tubuloalveolar gland and the tubules are parallel to each other and the spaces between the tubules are filled with connective tissue. The gland is covered by the conjunctival mucosa and the excretory ducts open onto the surface of the conjunctiva (Fahmy ***et al.***, 1971).

I.3. Scanning Electron Microscopy

I.3.A. The Cornea

A few scanning electron microscopic investigations have been performed on the corneal epithelium and endothelium of the dog (Stapleton Peiffer, 1979), cat (Peiffer, DeVanzo and Cohen, 1981), some domestic mammals (Kuwabara, 1983; Lavach, 1990,), cattle and horse (Gellatt, 1991).

The cells of the corneal epithelium of mammals are flat, polygonal and subdivided into dark and light cells (Kuwabara, 1985; Lavach, 1990; Eighth ***et al.***, 1997). In the dog (Stapleton and Peiffer, 1979), cat (Peiffer ***et al.***, 1981), cattle and horse, (Gelatt, 1991), the cells of the corneal endothelium are in the form of hexagonal cells.

In the camel, information pertaining to scanning electron microscopic investigations on the corneal epithelium and endothelium appears to be lacking.

I.3.B. The Retina

The available literature reveals that there is scanty information about the scanning electron microscopic investigation of the retina of domestic mammals. The scanning electron microscopy of the retinal pigmented epithelium of the ox, sheep, dog, monkey, rabbit, rat, chicken and man is briefly studied by Ts'o and Friedman (1967) and Eighth ***et al.*** (1997).

The retinal pigment epithelium of ox, sheep, dog, monkey, rabbit, rat, chicken and man is characterized by the remarkable regularity of the mosaic pattern of the hexagonal cells and particular combination of the various types of pigment granules (Ts'o and Friedman, 1967; Eighth ***et al.***, 1997).

The photoreceptor cells of domestic mammals are arranged as a mosaic and the variation in the density of both rods and cones appears in different regions of the retina (Eighth ***et al.***, 1997).

In the camel, with reference to the available literature, no scanning electron microscopic study was conducted on the retina.

I.3.C. The Third Eyelid

Scanning electron microscopic investigations on the nictitating membrane have been conducted on the ox, sheep and goat (Weyrauch, 1984). The cells of the epithelium of the nictitating membrane of the ox, sheep and goat are in the form of hexagonal cells and there are numerous goblet cells scattered between the cells of the surface epithelium. The cells of the surface epithelium and goblet cells of the ox, sheep and goat possess numerous microplicae and microvilli (Weyrauch, 1984).

In the camel, scanning electron microscopic investigation of the nictitating membrane is not found in the available literature.

I.4. Transmission Electron Microscopy

I.4.A. The Retina

The fine structure of the retinal pigment epithelium and photoreceptor layer of mammals have been studied by Mason, Fager and Abrahamson (1973), Wouters and DeMoor (1979), Dellmann and Brown (1981) and Braekevelt (1983a, 1983b, 1990a, 1990b, 1990c).

The retinal pigment epithelium of the ox (Mason ***et al.***, 1973), horse (Wouters and DeMoor, 1979), dog (Dellmann and Brown, 1981), pig, sheep, cat, monkey and duck (Braekevelt, 1983a, 1983b, 1990a, 1990b, 1990c) consists of a single layer of cubodial cells joined laterally by a series of tight junctions and basally they display numerous deep infoldings. The membrane facing the photoreceptor cells possesses tongue-like processes that extend from the cells to surround the outer segment of the rods over a short distance in most of mammals (Kuwabara, 1983). The fine microvilli which surround the outer segment of the photoreceptor of the horse (Wouters and DeMoor, 1979) are groove-like nonpigmented processes. The microvilli surround the entire

outer segment of the rods of the dog (Dellmann and Brown, 1981) while there are two types of processes, cylindrical sheath and slender microvilli, in man (Fawcett, 1994).

There are numerous mitochondria between the basal portion of the cell membrane and the nucleus in the ox (Mason ***et al.***, 1973), Nielson, Knave, Person and Lunt (1973a), horse (Wouters and DeMoor, 1979), dog (Dellmann and Brown, 1981) and man (Fawcett, 1994). The cytoplasm of the apical and middle portions of the cells contains an extensive system of granular endoplasmic reticulum, mitochondria, phagosomes, lysosomes and pigment granules in the frog (Porter and Yamada, 1960), ox (Mason ***et al.***, 1973), and horse (Wouters and DeMoor, 1979).

The photoreceptor cells of the ox (Mason ***et al.***, 1973a), horse (Wouters and DeMoor, 1979), dog (Dellmann and Brown, 1981), pig, sheep, cat, monkey and duck (Braekevelt, 1983a, 1983b, 1990a, 1990b, 1990c) are differentiated into rods and cones. The rods are long, slender cells while the cones are shorter and stouter. Both rods and cones consist of an outer segment, a connecting cilium and an inner segment.

Information pertaining to the ultrastructure of the retinal pigment epithelium and photoreceptor cells appears to be deficient in the camel.

I.4.B. The Third Eyelid

The epithelial cells of the third eyelid of mammals are polygonal in shape and are loosely packed with a relatively a few number of desmosomes (Kuwabara, 1983). The cell membranes are slightly interdigitated and form intercellular spaces and the cells are joined tightly with zonulae occludens (Eighth ***et al.***, 1997). Kuwabara (1983), Eighth ***et al.*** (1997) and Slatter (2001) reported that the cytoplasm contains fine filamentous matrix and a moderate number of microorganelles. Further

more, goblet cells are present and contain abundant mucin granules, rough endoplasmic reticulum and a Golgi apparatus.

The available literature lacks information about the ultrastructure of the nictitating membrane of the camel.

I.4.C. The superficial Gland of the Third Eyelid

In mammals, Bell (1971) and Montagna and Parakkal (1974) gave a detailed description of the sebaceous glands and subdivided the cells of the gland into: undifferentiated, differentiating and mature cells. The cytoplasm of the undifferentiated cells contains small Golgi complexes, free ribosomes, scattered mitochondria and bundles of tonofibrils (Montagna and Parakkal, 1974). The differentiating cells are round and consist of a spherical nucleus surrounded by sebum vacuoles (Bell, 1971).The mature cells are large and their surfaces are irregular with microvilli (Bell, 1971; Montagna and Parakkal, 1974).

In the camel, no ultrastructural investigations of the superficial gland are available.

I.4.D. The Deep gland of the Third Eyelid

A few reports have dealt with the ultrastructure of the Harderian gland in domestic mammals such as the rat (Paule and Hayes, 1958) hamster (Bucana and Nadakavukaren, 1972) fowl (Rothwell, Wight, Burns and Mackenzie, 1972), fowl, turkey, duck (Maxwell and Burns, 1979), dog (Martin ***et al.***, 1988), and buffalo (Abou-Elmaged, 1997).

The secretory cells of the Harderian gland, according to the above mentioned authors, are differentiated into light and dark cells, and the dark cells contain numerous ribosomes and large vacuoles. These secretory cells are characterized by the presence of a variable amount of secretory granules accumulating in the apical cytoplasm, a Golgi apparatus located in supranuclear area, rough endoplasmic reticulum and oval nuclei usually occupying the basal cytoplasm. The apical surface of

the secretory cells is covered by microvilli of variable length projecting into the lumen of secretory endpieces.

The cells of the epithelium of the duct of the fowl, turkey and duck are numerous and small and contain a network of rough endoplasmic reticulum and round mitochondria (Maxwell and Burns, 1979).

In the camel, the ultrastructure of the deep gland is given by Abou-Elmaged ***et al.*** (1990) and Abou-Elmaged (1992). Abou-Elmaged (1992) described the pattern of distribution of nerve terminals and their relation to the myoepithelial cells and the secretory cells.

I.5. Morphometric Study

The literature available to the author indicated that the morphometric study of the glands of the third eyelid of domestic mammals is scanty (Fateh el Bab ***et al.***, 1991).

A few morphometric investigations have been done on the glands of the third eyelid of the camel (Fateh el Bab ***et al.***, 1991). There are three types of endpieces in the Harderian gland. The first type is made up of light cells (78%), the second type of both light and dark cells (15%) and the third type of dark cells (7%).

CHAPTER TWO

MATERIAL AND METHODS

CHAPTER TWO
MATERIAL AND METHODS

II.1. Gross Anatomy

II.1.1. Material

The present study was conducted on fifty five heads of dromedary camels (*Camelus dromedarius*) of both sexes. The age of the camels ranged between two to fifteen years. Age determination was based on the formula given by Wilson (1984). The samples were collected from Al-Bogaa Slaughter-house. All specimens were taken from apparently healthy animals.

II.1.2. Methods

II.1.2.A. Topography

A total of ten heads of adult camels were used for the study of the topography of the eyeball and its appendages.

II.1.2.B. Weight and Measurements

The eyes were weighed after fixation in 10% formalin. The adipose tissue and extraocular muscles attached to the eyeball were removed first and then the eyeball was weighed on a laboratory balance. Ten eyeballs were used to determine the weight. A total of ten eyeballs were used to measure the length, width and circumference of the eyeball.

To determine the weight of the glands of the third eyelid, the superficial and deep glands, fixed specimens were used. Whole glands were carefully dissected out and weighed on a laboratory balance. The dimensions of the glands were also measured. The specimens were put on a flat surface and the length, width and thickness were measured with a ruler. Fresh specimens were used for the study of the colour, lobulation and shape of the glands.

II.2. Histology

Samples of eyeballs were obtained from twenty three heads of camels of both sexes of different age. Whole eyeballs were removed within five minutes after slaughtering the animals. Small pieces of tissue were fixed in different fixatives such as 10% formalin, 10% formal saline, Zenker's formol and Bouin's fluid (Culling, 1974). The best fixative for the eyeballs was found to be 10% formal saline.

The specimens of the eyeball were dehydrated in ascending grades of ethyl alcohol, cleared in chloroform, embedded in paraffin wax and sectioned in rotary microtome at 5µ thick (Drury and Wallington, 1980).

The sections were stained with hematoxyline and eosin (H&E) for general histology (Culling, 1974).

Special stains were used for the study of the following components:

1- Masson's trichrome and Van Gieson's stains were used to demonstrate collagen fibers and smooth muscle fibers (Drury and Wallington, 1980).

2- Orcein's, Verhoeff's and aldehyde fuchsin stains were used for the demonstration of elastic fibres (Bancroft and Stevens, 1996).

3- Gomori's silver impregnation method was conducted to demonstrate reticular fibres (collagen type III) (Drury and Wallington, 1980; Bancroft and Stevens, 1996).

4- Periodic acid-shiff's (PAS) technique (Bancroft and steven,1996), was used to investigate the presence of mucopolysacharides (diastase resistant material) and glycogen.

II.3. Scanning Electron Microscopy

Samples for scanning electron microscopy were obtained from three eyeballs from healthy adult camels. Small pieces of tissue were taken from the cornea, retina and nictitating membrane as soon as possible after death of the animals. The specimens were fixed with immersion in 2.5% gluteraldehyde in phosphate buffer pH (7.2) for two weeks (Glauert, 1974).

The specimens were washed in phosphate buffer pH (7.2) , dehydrated in ascending grades of ethanol, critical point-dried in liquid carbon dioxide, then coated with gold in sputter coating techniques.

The specimens were examined and photographed using JSM - 5400LV scanning electron microscope operated at the EM center of Assuit University. The cornea, retina and nictitating membrane were

scanned on their posterior and anterior surfaces. In addition, the retina was scanned on its cut surface to visualize its layers .

II.4. Transmission Electron Microscopy

Samples for ultrastructure were taken from three apparently healthy adult camels. Small pieces of tissue were taken from the third eyelid, superficial and deep glands of the third eyelid and the retina as soon as possible after death of the animals. The specimens were taken from different parts of the samples.

The specimens were fixed by immersion in 2.5% gluteraldehyde in phosphate buffer pH (7.2) for two weeks (Karnovsky, 1965; Glauert, 1974).

- The fixed tissue was washed in 0.1 M cacodylate buffer.
- The blocks were treated with 2% M osmium tertroxide for one hour and then washed in phosphate buffer pH (7.2) for one hour.
- Dehydrated in ascending gradates of alcohol.
- Cleared in propylene oxide, and embedded in epon-araldite mixture (Mollenhauer, 1964)
- Semi-thin sections were cut using a Reichert ultra-microtome and stained with buffered toluidine blue (Richardson, Jarett and Finak, 1960)
- All semi-thin sections were examined with the light microscope, photographed and the desired areas were chosen.
- Ultra-thin sections were cut and mounted on uncoated copper grids.
- ultra-thin sections were stained with lead citrate and uranyl acetate, and examined in Hitachi H-600 electron microscope in the EM center of Assiut University.

II. 5. Morphometric Study

A total number of six superficial glands of the third eyelid and six deep glands of the third eyelid of three adult camels were used. The glands of the third eyelid were chosen because they could be easily removed after slaughter and they are peculiar to the camel.

The water displacement technique of Aherne and Dunnil (1982) was used for the determination of the volume of the whole gland. For each specimen, the process of volume measurement was recorded three times and then the average volume as the mean value was calculated.

Each specimen was fixed by immersion in 10% formal saline. Each fixed gland was sliced into four parts of approximately equal size. All blocks from each gland were processed by the routine histological technique and embedded in paraffin wax. Serial sections of 7µ thick, were cut from each block.

The sections were stained with hematoxyline and easion. The best section from each block was selected for morphometric analysis. A total of 48 sections from 12 glands were studied. Morphometric analysis was carried out at the light microscopic level.

The selected sections were used for morphometric analysis to determine the volume densities (Vv) of the various components of the superficial and deep glands. The components of the superficial gland studied were: the glandular tissue, connective tissue, interlobular and main ducts and hair follicles; and the components of the deep gland were: the glandular tissue, connective tissue including cartilage, and interlobular and main ducts.

One section from each block was chosen and systemic randomly of 30 fields of each section of the superficial gland and 20 fields of each

section of the deep gland were analyzed by using a grid of 121-intersections, fitted with X 12.5 eyepiece (Olympus).

The number of points necessary to count for each parameter was determined by the plots of Weible (1963), giving standard error below 5%. However those parameters which occupied relatively small volumes did not fall within the scope of the plots.

The absolute volume of all the components of the gland were calculated from their volume densities (Vv) and from the total volume (V) of the fresh gland.

As suggested by Weibel (1963), the statistical analysis of the data obtained by the point counting was restricted to the calculation of the mean and standard deviation.

CHAPTER THREE

RESULTS

CHAPTER THREE

RESULTS

III.1.Gross Anatomy

III.1.1. Position and Topography of the Eyeball

The eyeballs of the dromedary camel were large and directed towards the lateral side of the orbit (Fig. 1) and they were enclosed in a considerable amount of adipose tissue (Fig. 2). The amount of the adipose tissue surrounding the eyeball decreased with advancing age.

The major part of the eyeball was covered by the periorbita and adipose tissue caudolaterally, while a small rostral part was covered only by the eyelids and conjunctiva.

III.1.2. Weight and Dimensions

The weight of the eyeball varied between 30.2 and 36.2 grams. The eyeball measured 3.5-3.7 cm. in length, 4.0-4.13 cm. in width and 13.0-13.5 cm. in circumference.

The cornea was oval in outline (Fig. 3) and measured 2.5-3.0 cm. in length and 2.0-2.5 cm. in width. The weight and size of the eyeball and cornea were increased with advancing age.

III.1.3. The Eyelids and Conjunctiva

There were two eyelids, upper and lower eyelids. They were situated in front of the eyeball (Fig. 1). The outer surface was covered by the skin and the inner surface was covered with conjunctiva. The skin was thick, large and prominent laterally.

The two eyelids were joined to form the medial and lateral angles or canthi. The free borders of the eyelids were smooth and usually pigmented (Fig. 1). The two eyelids were extensive and moved freely. The outer surface of the skin was provided with short hairs.

The conjunctiva was a thin, transparent mucous membrane, pink in colour and smooth. It lined the inner surface of the upper and lower eyelids as the palpebral conjunctiva. It was continued onto the front surface of the eyeball as the bulbar conjunctiva which terminated at the margin of the cornea. It also lined the third eyelid and superficial and deep glands of the third eyelid. The potential space between the eyelids and the eyeball was called conjunctival sac. There was a dark pigmented line at the free margin of the upper and lower eyelids. Darkly pigmented areas were observed in several horizontal lines on the caudal half of the conjunctiva and these lines represented the subconjunctival lymph nodules.

III.1.4. The Eyelashes

The eyelashes were situated at the margin of the eyelids and they were long, strong and densely packed. Moreover, there was a triangular hairy tuft on the medial portion of the margin of the upper eyelid and peculiar hairs (Fig. 1).

III.1.5. The Third Eyelid

The third eyelid (palpebra tertia) was situated on the rostromedial aspect of the eyeball and quadrilateral in outline (Fig. 2). It measured between 35.3 to 4.02 cm. in length and 1.93-2.15 cm. in width. It was formed of irregular cartilaginous plates which were covered by a fold of conjunctiva. It had two surfaces: the bulbar surface and the palpebral surface. The bulbar surface was concave as it was pressed against the convex eyeball. The palpebral surface was convex in adaptation to the concavity of the eyelid. The deep part of the third eyelid was narrow, thick and embedded in adipose tissue.

The superficial part of the third eyelid showed dark pigmentation at its free margin (Fig.2). Another dark pigmentation appeared at the line of reflection of the conjunctiva onto the superficial gland of the third eyelid,

especially in old animals. Numerous nodular structures were present in the conjunctiva covering the third eyelid.

III.1.6. The Glands of the Third Eyelid

The glands of the third eyelid were two in number, the superficial and deep gland. They were situated on the medial canthus.

III.1.6.A. The Superficial Gland

The superficial gland consisted of numerous lobules of different sizes and shape, scattered adjacent to the base of the third eyelid. It was triangular in shape, flat and bright rosey red in colour (Fig. 2).

It had two surfaces: medial and lateral. The two surfaces possessed a few scattered hairs.

The conjunctiva, covering the superficial gland, was clearly pigmented.

The average dimensions and weight of the superficial gland of the third eyelid is shown in table (1).

III.1.6.B. The Deep Gland

The deep gland was situated at the lower part of the bulbar surface of the third eyelid. The upper part of the gland was related to the superficial gland, whereas the lower part of the gland was covered only by adipose tissue and fascia. The gland appeared as one unit which had two surfaces and three margins . Its lobules were intimately packed together and to the cartilage of the third eyelid.

The deep gland was brown in colour. The shape of the gland was irregularly oval. The gland possessed 3-5 small excretory ducts. The caudal or terminal ends of the main ducts showed some pigmented streaks along the borders of the gland (Fig. 4).

The average dimensions and weight of the deep gland of the third eyelid is shown in table (1).

Table (1): Showing the average dimensions and weight of the superficial and deep glands of third eyelid.

The gland	Weight (gm.)			Length (cm.)			Width (cm.)			Thickn (cm	
	Min.	Max.	Aver.	Min	Max	Aver	Min	Max	Aver	Min	Max
Superficial	1.50	3.00	2.00	3.00	3.80	3.40	1.70	2.50	2.10	0.60	0.50
Deep	3.10	3.80	3.45	2.70	3.30	3.00	2.10	2.30	2.20	0.60	0.70

III. 2. Histology

III.2.A. The Eyeball

The wall of the eyeball (*Bulbus oculi*) of the dromedary camel was subdivided into three main tunics : fibrous, vascular and nervous tunics.

III. 2. A. 1 The Fibrous Tunic

The fibrous tunic (*tunica fibrosa bulbi*) included the sclera and the cornea (Fig. 3).

III.2.A.1.A. The Sclera

The sclera was a white and tough layer that covered the posterior portion of the eyeball (Fig. 3). It consisted of two layers, the sclera proper and the lamina fusca sclerae.

The outer surface of the sclera proper was covered by adipose tissue and bundles of muscles fibres (Fig. 5). The sclera proper was composed of a dense irregular connective tissue consisting mainly of large bundles of collagen fibres (Fig. 5) and elongated fibroblasts embedded between the collagen bundles. These bundles were arranged parallel to the surface of the eyeball. Within the bundles, large and medium-sized blood vessels were present. Melanocytes were demonstrated surrounding the blood vessels either individually or in focal collections.

The lamina fusca sclerae was composed of irregular connective tissue consisting mainly of large bundles of collagen fibres. Numerous branched melanocytes were observed in the deep part of this layer. Numerous small blood vessels were observed.

III.2.A.1.B. The Cornea

The cornea was pigmented at the corneoscleral junction (limbus). It consisted of four layers: the corneal epithelium, corneal stroma, Descemet's membrane and corneal endothelium.

III.2.A.1.B.1. The Corneal Epithelium

It covered the anterior surface of cornea and consisted of stratified squamous nonkeratinized epithelium. The epithelium was arranged in 10-12 layers of non-keratinized cells (Fig. 6). It was thinnest at the center of the cornea, and the thickness and number of cell layers increased towards the limbus.

The outer surface was quite smooth and composed of large squamous cells. The inner surface was devoid of papillae. The cells of the epithelium were subdivided into three layers: basal, intermediate and superficial layers (Fig. 6). The basal layer consisted of columnar cells with oval or rounded centrally situated nuclei and lightly stained cytoplasm and they were arranged in one layer. This layer rested on a distinct and thin basement membrane (Fig. 6). The intermediate layer was composed of cubodial cells which formed most of the corneal epithelium. The cubodial cells were arranged in about 8 layers and their nuclei were mostly oval in shape and had lightly dark cytoplasm. The transition to the superficial layer was not distinct. The superficial layer was composed of large squamous cells which were represented by 5 layers of spindle shaped cells with flattened darkly stained nuclei. At the limbus, the epithelium was highly pigmented due to the presence of large branching pigment cells. The corneal epithelium showed P.A.S positive reaction and the basal cells contained abundant small-sized P.A.S positive granules (glycogen).

III.2.A.1.B.2. The Corneal Stroma

The corneal Stroma was composed of dense irregular connective tissue consisting mainly of large bundles of collagenous fibers (Figs. 6, 7 and 8), and fibroblasts were observed between these bundles. A few

capillaries were also observed within the bundles adjacent to the epithelium of the corneoscleral junction.

Also at the corneoscleral junction, the stroma contained pigment cells which were large in size and arranged between the bundles of the collagen fibers (Fig. 8). The stroma showed moderate reaction with P.A.S technique.

III.2.A.1.B.3. The Descemet's Membrane

The Descemet's membrane was a thick, homogenous membrane separating the corneal stroma from the corneal endothelium (Fig. 7). A strong P.A.S positive reaction was represented by a pinkish color of the membrane.

III.2.A.B.4. The Corneal Endothelium

The corneal endothelium covered the posterior surface of the cornea and consisted of a single layer of flat hexagonal or low cubodial cells.

III.1.A.2. The Vascular Tunic

The vascular tunic (*Tunica vasculosa bulbi*) was divided into three parts: the choroid, iris and ciliary body.

III.2.A.2.A.The Choroid

The choroid was a darkly pigmented thin layer situated adjacent to the inner surface of the sclera. It extended from the optic disc to the ciliary ring. It was subdivided into four layers, from outside inwards: the suprachoroid, vascular and choriocapillary layers and the Bruch's membrane.

III.2.A.2.A.1. The Suprachoroid Layer

It was composed of a dense irregular connective tissue consisting mainly of small bundles of collagen fibers. A large number of branched melanocytes of irregular shape were scattered within the connective tissue (Figs. 9 and 10).

III.2.A.2.A.2. The Vascular Layer

It was composed of medium size arteries and veins within a loose irregular connective tissue layer consisting mainly of small bundles of collagen fibres rich in melanocytes (Fig. 9 and 10). The stroma also showed scattered smooth muscle fibers.

III.2.A.2.A.3. The Choriocapillary layer

It was in the form of a dense network of capillaries within a loose irregular connective tissue layer which consisted mainly of small bundles of collagen fibers immediately adjacent to the vascular layer. The capillaries had a large and somewhat irregular caliber (Fig. 10). Numerous melanocytes were observed within the bundles of the collagen fibers (Figs. 9 and 10).

III.2.A.2.A.4. The Bruch's Membrane

The Bruch's membrane (*lamina basalis*) was the most inner layer of the choroid. It was thin, homogenous and separated the choriocapillary layer from the pigmented epithelium of the retina (Fig. 10).

III.2.A.2.B. The Ciliary Body

The ciliary body was the direct anterior continuation of the choroid. It consisted of the ciliary epithelium, ciliary stroma, ciliary muscle and ciliary processes (Figs. 11 and 12).

III.2.A.2.B.1. The Ciliary Epithelium

The ciliary epithelium consisted of two layers: an inner layer of non-pigmented elements bounding the posterior chamber, and an outer layer of pigmented layer resting on the stroma of the ciliary body. The non-pigmented layer was composed of columnar cells with oval or irregular nuclei. The pigmented layer consisted of cubodial or low columnar cells with oval or irregular nuclei. The cells of the pigmented epithelium contained melanin granules (Figs. 11 and 13).

III.2.A.2.B.2. The Ciliary Stroma

The ciliary stroma was composed of loose irregular connective tissue consisting mainly of small bundles of collagen fibers (Fig. 11). Arteries and veins of varying caliber were demonstrated within the ciliary stroma.

III.2.A.2.B.3. The Ciliary Muscle

The ciliary muscle was a thin layer of smooth muscle fibers (Fig. 11). The smooth muscle fibres radiated in a fan-like pattern from the inner surface of the sclera toward the cavity of the eyeball.

III.2.A.2.B.4. The ciliary processes

The ciliary processes were formed by thickenings of the vascular layer (Fig. 12). They consisted of stromal cores of loose connective tissue consisting mainly of small bundles of collagen fibres and numerous blood vessels. The processes were covered by an inner non-pigmented and an outer pigmented epithelium. The non-pigmented epithelium was columnar in shape with oval or irregular nuclei. The pigmented epithelium was either cubodial or low columnar in shape with spherical or oval nuclei (Fig. 13). The zonular fibres were situated between the ciliary process and attached near the periphery of the lens.

III.2.A.2. C The Iris

The iris was situated between the cornea and the lens, dividing the anterior part of the eye into anterior and posterior chambers. It was composed of the iris epithelium , iris stroma , iris muscle and iris granules. The iris angle was formed between the corneoscleral junction, the base of the ciliary body and the ciliary border of the iris (Fig. 12).

III.2.A.2.C.1.The Iris Epithelium

The iris had two surfaces: an anterior and posterior surfaces .The anterior surface was covered by a thin epithelial layer of flat and discontinuous cells underlined by a thin layer of spindle-shaped melanocytes (Fig. 14). The posterior surface was covered by a thick

pigmented epithelial layer of cubodial to low columnar pigmented cells which were filled with dark brown and coarse melanin granules (Fig. 15).

III.2.A.2.C.2.The Iris Stroma

The subepithelial layer of both surfaces of the iris was supported by a loose irregular connective tissue consisting mainly of a network of collagen fibers. Numerous blood vessels were observed within the stroma. A large number of irregular melanocytes were demonstrated within the Stroma (Figs. 14 and 15).

III.2.A.2.C.3.The Iris Muscle

The iris muscles were represented by the dilator and sphincter pupillary muscles. The dilator muscle consisted of a thin membrane of radially arranged myoepithelial elements situated between the iris stroma and the posterior pigmented epithelium of the iris.

The sphincter muscle was a thin and flat ring of smooth muscle fibres surrounding the margin of the pupil (Fig. 16).

III.2.A. 2.C.4. The Iris Granules

The iris granules (Granula iridica or Corpora nigra) were located at the ventral and dorsal pupillary margins. They were represented by highly vascularized proliferations of the stroma of the iris and the pigmented epithelium. They were small cystic formations lined by pigmented epithelial cells and associated with a complicated glomus-like capillary network.

III.2.A.3. The Nervous Tunic (The Retina)

The retina (*Tunica interna bulbi*) was the innermost layer of the eyeball. The outer surface was in contact with the choroid and its inner surface with the hyaloid membrane of the vitreous body. The retina consisted of ten parallel distinct layers, from outside inward as follows :

III.2.A.3.1. Pigment Epithelium

The pigment epithelium was a single layer of cells adjacent to the Bruch's membrane. It consisted of 1-2 layers of simple squamous cells with flat nuclei and pigment granules (Figs. 9 and 10).

III.2.A.3.2. Photoreceptor Layer

The photoreceptor layer consisted of two kinds of cells, the rod cells and the cone cells (Fig. 17). They were long, slender cells oriented parallel to one another. The rod cells greatly outnumber the cone cells. The cone cells were wider than the rod cells at their bases. The cone cells were very regular in outline and were distributed among the rod cells .

III.2.A.3.3. Outer Limiting Membrane

The outer limiting membrane was a thin membrane separating the rod and cone cells layer from the outer nuclear layer. It appeared as a dense line (Fig. 17).

III.2.A.3.4. Outer Nuclear Layer

The outer nuclear layer contained the nuclei of the rod and cone cells (Fig. 17). The perikarya of the cones were located in the outer part and form only a single row whereas the perikarya of the rods form several rows in the inner part of this layer.

III.2.A.3.5 Outer Plexiform Layer

The outer plexiform layer was in the form of an intricate zone of fibres (Fig. 17).

III.2.A.3.6. Inner Nuclear Layer

The inner nuclear layer contained different types of cells. It was thinner than the outer nuclear layer (Fig. 17).

III.2.A.3.7. The Inner Plexiform Layer

The inner plexiform layer consisted of fibres between the bipolar layer and the layer of ganglion cells (Fig. 17).

III.2.A.3.8. Ganglion Cells Layer

The ganglion cells layer was formed by the cell bodies of large nerve cell bodies.

III.2.A.3.9. Layer of Optic Nerve Fibres

It was a layer which consisted of nerve fibres.

III. 2.A.3.10. Inner Limiting Membrane

The inner limiting membrane appears as a thin limiting membrane.

III.2.B. The Appendages of the Eyeball

The appendages of the eyeball included the two eyelids, upper and lower eyelid, the conjunctiva, the third eyelid and two glands associated with the third eyelid.

III.2.B.1. The Upper and Lower Eyelid

The outer surface of both eyelids was covered by the skin. It was lined by several layers of keratinized stratified squamous epithelium (Fig. 18). It was either smooth or irregular and contained ridges and grooves. The epithelium had few papillae. The dermal papillae were short, broad and prominent in some regions with or without a few hairs.

The inner surface of both eyelids was lined by several layers of non-keratinized stratified squamous epithelium (Fig. 19) with large goblet cells (Figs. 19 and 20).

The subepithelial layer of both surfaces was composed of dense irregular connective tissue. The connective tissue consisted mainly of large bundles of collagen fibers (Figs. 19 and 20), and a few elastic and reticular fibers (Fig. 24). Many blood vessels and adipose tissue were observed in the lamina propria. Melanocytes were also observed in the lamina propria of both surfaces.

Lymphocytes were demonstrated either dispersed or scattered in the lamina propria or in the form of lymph nodules without germinal centers (Fig. 19). Hair follicles were seen in the lamina propria of the outer surface. The hair follicles were present either singly or grouped into

distinct clusters. Each of these groups consisted of two to five hair follicles which were surrounded by a sheath of connective tissue.

Sinus hair follicles were also observed in the lamina propria. They were highly developed and consisted of five layers: an outer layer of the dermal sheath, blood sinus, inner layer of the dermal sheath, glassy membrane and external root sheath of the hair follicles. The outer layer of the dermal sheath was composed of a dense irregular connective tissue consisting of small bundles of collagen fibers (Figs. 21 and 22). It was highly vascular and contained numerous nerves inside the bundles (Fig. 22). In each sinus hair follicles a blood sinus was observed between the inner and outer layers of the dermal sheath. It was lined by endothelial cells and supported by trabeculae of connective tissue connecting the inner and outer layers of the dermal sheath (Figs. 21 and 22). No arrector pili muscles were seen associated with the sinus hair follicles.

Sebaceous and sweat glands were generally situated inside the connective tissue adjacent to the outer surface of both eyelids.

The sebaceous glands were either simple branched or compound alveolar. They were connected to the external root sheath of hair follicles, into which the ducts empty and formed pilosebaeous canal of hair follicles. Some ducts also opened into the palpebral surface of the margin of the outer surface. The glands consisted of several layers of polygonal glandular cells. The cells were flattened at the periphery and then became polyhedral cells which were gradually enlarged toward the center. The cells contained rounded and centrally situated nuclei. The ducts were lined by stratified squamous epithelium.

The multilobulated tubulo-alverolar modified sebaceous glands, which were referred to as the tarsal glands, were absent in all the specimens studied.

The sweat glands were also observed in the subepithelial layer of both eyelids (Fig. 23). They were simple, coiled and tubular. They were associated with large hair follicles. They were situated in the connective tissue below the level of the sebaceous glands, and usually clustered around the hair bulb.

The secretory portion of the glands was lined by a single layer of epithelial cells. The epithelial cells were either oval or spherical and were separated from the basement membrane by elongated myoepithelial cells (Fig. 23). The ducts opened into the hair follicles above the opening of the ducts of the sebaceous glands. No duct was observed to open directly onto the outer surface. The lining epithelium of the ducts was generally made up of two layers of cubodial cells (bistratified epithelium).

III.2.B.2.The Conjunctiva

The conjunctiva was lined by several layers of stratified squamous epithelium with large goblet cells (Fig. 19). The goblet cells showed P.A.S positive reaction (Fig. 20). The basal cells of the epithelium were columnar and contained oval nuclei. The intermediate polyhedral cell layers consisted of several rows of cells and contained large rounded to oval central nuclei. The upper most layer consisted of flat cells with oval or flat nuclei.

The subepithelial layer consisted of irregular layer of connective tissue of large bundles of collagen fibers (Figs. 19 and 20). Numerous blood vessels were observed within the subepithelial layer.

In addition, lymph nodules were observed in the palpebral conjunctiva (Fig. 19).

III.2.B.3. The Third Eyelid

The third eyelid (*Palpebra tertia*) was surrounded on both surfaces by non-keratinized stratified squamous epithelium (Figs.27 and 28) with large goblet cells (Figs. 26 and 28). The goblet cells were either

arranged singly or in aggregations. Most of the goblet cells showed P.A.S positive reaction while a few goblet cells were P.A.S negative (Fig. 26). The pigmented granules were observed within the epithelial cells (Fig. 27). The two surfaces of the third eyelid were either regular or irregular in outline.

The subepithelial layer consisted of irregular connective tissue, consisting mainly of small bundles of collagen (Figs. 25 and 27) and a few elastic fibers. Many blood vessels were observed in the lamina propria. The basal lamina, the connective tissue and the blood vessels were moderately P.A.S positive (Fig. 26).

Lymphocytes were also observed within the lamina propria under the epithelial layer of the bulbar conjunctiva in the form of lymphatic infiltration. Lymphocytes were also observed in the form of several lymph nodules beneath the surrounding epithelium at the line of the conjunctival reflection from the third eyelid on to the upper and lower eyelids superficially and the eyeball deeply.

Several platelets of hyaline cartilage were present within the stroma of the third eyelid. They were encapsulated within a perichondrium and surrounded by a thick layer of irregular connective tissue (Figs. 25, 26 and 27). The connective tissue was composed of dense small bundles of collagen fibers.

P.A.S reaction in the hyaline cartilage was represented by a pinkish line surrounding the chondrocytes and a strong positive reaction was seen in the chondrocytes themselves (Fig. 26).

III.2.B.4. The Glands Associated with the Third Eyelid

The glands associated with the third eyelid were classified into superficial and deep glands.

III.2.B.4.A. The Superficial Gland

The superficial gland (nictitan gland) was covered by a thick irregular connective tissue capsule. The outer surface of the capsule was lined by stratified squamous epithelium (Fig. 32) with large goblet cells. The capsule consisted of dense bundles of collagen fibers together with a few elastic and reticular fibres. The goblet cells showed P.A.S positive reaction.

The epithelium was arranged into 5-7 layers of non-keratinized cells. There were trabeculae extending from the inner surface of the capsule dividing the gland into many small lobules (Fig. 32). The trabeculae had the same components of the capsule (Figs 29, 30, 32 and 33). The lobules were parallel to each other and they were made up of acini which were continuous with short ducts. The acini had no lumen. Each lobule was formed of branched tubulo-alveolar gland which are sebaceous in type (Figs. 29, 30, 31 and 32).

Each alveolus was composed of undifferentiated cells and differentiating cells (Figs. 33 and 34). The undifferentiated cells were flat peripheral cells followed by several layers of low cubodial cells with round nuclei. They rested on the basal lamina (Figs. 29, 30, 32 and 33). Toward the center of the alveoli, most of the cells became large and polyhedral in shape and they were referred to as differentiating cells. These cells were gradually filled with fat droplet and resembled adipocytes (Fig. 34). The alveoli of the gland were surrounded by interlobular connective tissue consisting of small bundles of collagen (Figs. 29, 30, 31 and 32), a few elastic and reticular fibers. Numerous myoepithelial cells were observed within the interlobular connective tissue (Fig. 34). The interlobular connective tissue contained many lymphocytic infiltration and lymphatic nodules observed in the capsule near the covering of the bulbar conjunctiva.

One or two alveoli were associated with each hair follicle and the hair was usually inserted obliquely (Figs. 29 and 30). The epidermal root sheath of the follicles of these hairs showed dark brown pigments.

The interlobular ducts were lined by stratified squamous epithelium with goblet cells and they continued with the lining epithelium of the hair follicle. These ducts opened into either a pilosebaeous canal around the hair shaft (Fig. 31), into invagination from the surface epithelium or through the neck of hair follicles where hairs were present. The interlobular ducts were surrounded by loose connective tissue and embedded in adipose tissue. Aggregations of lymphocytes were observed within elastic and reticular loose connective tissue that surrounded the ducts.

III.2.B.4.B. The Deep Gland

The deep gland (Harderian gland) was surrounded by a capsule of irregular tissue consisting mainly of dense small bundles of collagen fibers (Fig. 35) together with elastic (Fig. 36) and reticular fibres. The outer surface of the capsule was covered by several layers of stratified squamous epithelium with large goblet cells. The goblet cells were strong P.A.S positive. Blood vessels, fibroblasts and lymphocytes were observed within the connective tissue of the capsule.

The inner surface of the capsule gave rise to a variable number of thick branching septa. The thick septa passed from the capsule and entered the parenchyma of the gland dividing it into varying number of lobules of different shapes and size. The septa had the same components of the capsule (Fig. 35).

The parenchyma of the lobules was composed of tubulo-alveolar secretory endpieces of small size. Each endpiece was lined with pyramidal or columnar cells with basally situated nuclei. The endpieces possessed either narrow or wide lumina (Figs. 35, 36 and 42). P.A.S

staining gave variable degree of reaction among these secretory cells. Some lymphocytes were infiltrated between the acinar cells of the gland.

The secretory cells of the gland endpieces were differentiated into light and dark cells (Figs. 41 and 42). The majority of the glandular endpieces were formed of both light and dark cells, yet a few endpieces which consisted only of light or dark cells.

Myoepithelial cells were demonstrated between the basal border of the secretory cells of the endpieces and the basal lamina. Their nuclei were oval in shape. Numerous plasma cells were also observed within the interstitial connective tissue (Fig. 41). Loose capillary networks surrounded the terminal portion of the endpieces.

The intralobular ducts were lined by a single layer of cubodial cells with round or oval nuclei (Fig. 36), while the interlobular ducts were lined by one or two layers of cubodial cells with round or oval nuclei (Figs. 37, 39 and 41). The ducts were surrounded by a layer of irregular connective tissue of small bundles of collagen (Figs. 39 and 41), a few elastic and reticular fibers (Fig. 37). Numerous lymphocytes were scattered within the interstitial connective tissue. The lining epithelium of the ducts showed many pigmented granules.

The main ducts opened on the palpebral conjunctival surface of the gland. They were lined by 3-4 layer of cubodial cells. The wall of the ducts presented several pigmented granules (Fig. 40). There were varying number of large goblet cells interspersed among the epithelial cells. The goblet cells showed strong P.A.S positive reaction. The ducts were surround by loose irregular connective tissue of small bundles of collagen, elastic and reticular fibres. Blood vessels and nerve fibers were observed in the interstitial connective tissue. Among the ducts, clusters of lymphocytes were found either with or without germinal centre, or as diffuse lymphocytes.

At the border of the glandular tissue, adjacent to the capsule, there were aggregations of lymphocytes. These lymphocytes formed small solitary lymphatic nodules, but germinal centres were rarely seen (Fig. 35). Within the lobules, large irregular adipocytes were observed either singly (Figs. 35 and 40) or as aggregations (Fig. 37) between the secretory endpieces. Also the aggregations of the adipocytes were observed within the interstitial connective tissue.

Several platelets of hyaline cartilage were present within the glandular tissue. They were encapsulated within a perichondrium (Fig. 38).

III.3. Scanning Electron Microscopy

III.3.A.The Cornea

The corneal epithelium and corneal endothelium were studied.

III.3.A.1. The Corneal Epithelium

The corneal epithelium was arranged into several layers of flattened superficial cells (Fig. 43). These cells were mostly hexagonal in shape and were closely packed to each other by relatively straight cells boundaries (Fig. 44). The cells were classified into light and dark cells of varying density (Figs. 43 and 44). The surface of the epithelial cells possessed numerous large microvilli and microplicae. The light cells contained more microvilli and microplicae (Fig. 44). Cells in the central cornea possessed numerous large microvilli and microplicae than those in the periphery.

III.3.A.2. The Corneal Endothelium

The corneal endothelial cells were arranged in a mosaic-like pattern of hexagonal cells. These cells were small in size and had distinct boundaries (Fig. 45). The surface of these cells possessed a few microvilli which were condensed at the centre of the cells (Figs. 46 and 47). The lateral edges of the cells interdigitated with each other. This interdigitation was very clear giving the border a zigzag appearance (Fig. 47). The cells were characterized by the presence of large and centrally located nuclei (Figs. 46 and 47). The nuclei bulged into the anterior chamber of the eye.

III.3.B. The Retina

Three layers only of the retina were scanned: the pigment epithelium, the photoreceptors and the optic nerve fibre layer.

The retinal pigment epithelium was characterized by the remarkable regularity of the mosaic pattern of the basic hexagonal cells. These cells were mostly hexagonal in shape and were closely packed to

each other by relatively straight cell boundaries (Fig. 48). The retinal pigment cells were mononucleate. The retinal pigment epithelium was characterized by a combination of various types of pigment granules. The pigment granules were mainly either spherical or spindle shaped.

The photoreceptor elements (rods and cones) protruded beyond the outer limiting membrane. The photoreceptors were arranged as a mosaic (Figs. 49 and 50). The composition of the mosaic pattern varied from region to region due to the variations in the density of the rods and cones. The photoreceptors were divided into two portions: inner segment and outer segment.

The outer segments appeared as fingerlike bodies (Figs. 49 and 50). The cones had large profiles while the rods had small profiles (Fig. 51).

The outer limiting membrane and outer nuclear layer were clearly observed and the outer nuclear layer was formed of mosaic-like dome-shaped pattern (Figs. 49 and 50).

The layer of the optic nerve fibres was arranged in a simple radial pattern. The fasciculation of the nerve fibre was observed (Fig. 52).

III. 3.C. The Third Eyelid

The epithelium of the third eyelid formed a mosaiclike pattern of hexagonal cells (Figs. 53 and 54). The cells possessed numerous microvilli on their surface (Fig. 56) and they were classified into light and dark cells. The light cells were characterized by a few microvilli and a thick mucous coat. The dark cells were slightly depressed below the surface and they were large and were equipped with short and broad microvilli.

Goblet cells were observed within the hexagonal cells. The goblet cells contained a central tuft of microvilli (Fig. 55). Radial microvilli traversed the surface opening, and the border was delineated by a row of

tall microvilli. The goblet cells appeared as small dark craters interposed between the epithelial cells. Dark cells with short regular and tightly packed microvilli were observed.

III.4. Transmission Electron Microscopy

III.4.A. The Choroid and Retina

III.4.A.1. The Choroid

Bruch's membrane consisted of a basal lamina of the retinal pigment epithelium, inner layer of collagen fibres and elastic layer, outer layer of collagen fibres and basal lamina of choriocapillary endothelium. The choriocapillary endothelium was a single layer of large anastomosing capillaries which were fenestrated (Fig. 58).

Numerous melanocyte were observed within the connective tissue of the choriocapillary layer. Its cytoplasm was crowded with melanin granules. The nucleus was spherical and showed euchromatin (Fig. 57).

III.4.A.2. The Retinal Pigment epithelium

The retinal pigment epithelial cells were hexagonal in shape, with basal and apical membranes. The basal membrane was slightly folded and formed the innermost portion of Bruch's membrane.

The apical membrane possessed microvilli which had many melanin granules and they were closely attached to the outer segments of the rods.

The cytoplasm of the cells of the pigment epithelium contained a centrally or basally located large nuclei. The chromatin material was seen in clusters around the nuclear membrane and at the center of the nucleus (Figs. 59 and 60). Mitochondria were located in the basal region of the cell. Smooth endoplasmic reticulum was plenty, while rough endoplasmic reticulum was very scarce.

Large, centrally located lipid droplets were observed. Melanin granules with a rounded shape were found in the apical cytoplasm (Figs. 58, 59 and 60). Phagosomes were present in the cytoplasm in varying number and size. They were located next to the pigment epithelium basal lamina.

The adjacent cells were connected to each other by a junctional complex consisting of apical gap junctions, followed by tight junction and a zonula adherens. Large number of nuclear pores were present in the nuclear membrane of the retinal pigment cell (Fig. 60).

III.4.A.3. The Photoreceptors Layer

The outer segment of the rods was composed of a very large number of parallel lamellae which were mainly enclosed within the cell membrane. A connecting cilium was observed between the inner and outer segments.

The apical region of the outer segment was rich in long and slender mitochondria (Fig. 61).

The outer segment of the cones also was composed of a large number of discs stacked one above the other. Each of these consisted of a pair of membranes. The cone outer segment was also connected to the inner segment by a connecting cilium.

The cone inner segment possessed a number of highly elongated mitochondria just below the connecting cilium (Fig. 61). The cytoplasm of inner segment of the cones was typically slightly more electron dense than that of the rods.

III.4.A.4. The Outer Limiting Membrane

The outer limiting membrane was formed by a series of zonulae adherent between rods, cones and Muller cell (Fig. 61).

III.4.A.5. The Outer Nuclear Layer

The nuclei of rods were round to oval in shape and display a dense heterochromatin pattern and these nuclei were located at the levels of the outer nuclear layer (Fig. 62). Cone nuclei were formed a single discontinuous row immediately below the inner limiting membrane (Fig. 61). Cone nuclei were larger and more vesicular than the rods nuclei.

III.4.B. The Third Eyelid

The epithelial cells of the third eyelid were classified into superficial, intermediate and basal cell layers. The superficial cells were tall columnar with long straight apical microvilli. They were loosely packed and joined together with a relatively small number of desmosomes. Their nuclei were round to oval in shape and they occupied the basal cytoplasm. Their cytoplasm contained microfilaments. The cells were joined at their anterior contiguous border by junctional complexes consisting of zonula occludens, zonula adherens and a macula adherens. These junctional complexes sealed the intercellular space anteriorly. The intermediate cells were polygonal in shape. Desmosomes were evident along the lateral cell borders.

The basal cells contained large electron-dense nuclei. The basal cell membrane was smooth in some cells and folded in others and rested either on myoepithelial cells with desmosomal attachments or on a thin basal lamina with hemidesmosomal attachments. The myoepithelial cell nucleus was oval with marginal heterochromatin. The myoepithelial cells were observed within the epithelial basal lamina. A thin basal lamina en-sheathed the epithelial cells, following their irregular contours, and hemidesmosomes were scattered on the basal surface of the myoepithelial cells.

The interstitial connective tissue consisted of large bundles of collagen fibres, fibroblast (Fig. 66) and lymphocytes.

There were numerous goblet cells among the epithelial cells. These goblet cells were observed either singly (Figs. 63, 64 and 65) or grouped in association with an epithelial crypt .They were found within the cells of the basal layer of the epithelium and tended to retain attachment to its basal lamina (Figs. 63, 64 and 65). They were round to oval in shape with flat or oval nuclei (Fig. 65). They contained both dark (Fig. 65) and light (Figs. 63 and 64) mucous granules with the largest granules in the apical cytoplasm. The content of these large granules was more homogenous and less electron dense than that of the deeper granules (Figs. 63 and 64). Moreover, goblet cells with electron dense basal nucleus and a relatively dense cytoplasm were demonstrated. They were attached to adjacent epithelial cells by small desmosomes.

The granules appeared to be larger and more oval as they approached the surface of the epithelium. Ultimately the apical plasma membrane was ruptured thus discharging their mucous granules onto the apical surface of the epithelial cells (Fig. 63). The apical surface of the goblet cells usually presented numerous microvilli (Figs. 63 and 64).

III.4.C. The Superficial Gland

The undifferentiated cells rested on the basal lamina of the alveoli. Their nuclei were round to oval with marginal heterochromatin and they occupied the basal cytoplasm (Fig. 67). Tonofilaments, which formed fine bundles of tonofibrils, and free ribosomes were seen in the cytoplasm of the undifferentiated cells (Figs. 67 and 69). Desmosomal attachments were observed between adjacent undifferentiated cells. Hemidesmosomes connected the undifferentiated cells and the basal lamina.

The differentiating cells contained numerous free ribosomes and variable numbers of different-sized sebum vesicles. The smaller vesicles

contained somewhat uniformly dense material. The larger vesicles were irregular in shape. Their nuclei were round to oval in shape and they occupied the basal cytoplasm. Melanin granules with a rounded shape were found in the apical cytoplasm (Fig. 68). The plasma membrane of differentiating cells was mostly smooth and contained shallow invaginations which were either pressed against the surface of another cell or interdigitated with it. Small desmosomes and tight junctions connected adjacent cells.

The mature cells were large and often deformed cells. Their surfaces were irregular with microvilli extending into the surrounding space. Small desmosomes were found between adjacent cells. Their cytoplasm contained small smooth- surfaced vesicles, some ribosomes, tonofilaments near the plasma membrane and small dense mitochondria. Most sebum vacuoles were nearly of uniform size. All vesicles contained a dense cloudy substance.

Myoepithelial cells were observed between the basal lamina and the basal border of the undifferentiated cells. They were identified by their electron dense myofilaments filling most of their cytoplasm. Each myoepithelial cell consisted of a cell body and cytoplasmic processes. The cell body was large and oval or triangular in shape and the cytoplasm contained oval or elongated nucleus. The cytoplasmic processes were slender in shape. The plasma membrane of myoepithelial cells was firmly attached by hemidesmosomes to the relatively thick basal lamina. Small desmosomes connected the plasma membrane of myoepithelial cells and plasma membrane of undifferentiated cells. The interstitium between adjacent alveoli varied from only small space containing a few collagen fibers separating adjacent basal laminae, to larger spaces containing small blood vessels, unmyelinated nerve fibers, plasma cells and a few fibroblasts. The capillaries in the interstitial spaces were fenestrated.

Nerve terminals with accumulations of a few electron dense granules and many small agranular vesicles, as well as large clear vesicles and a few round mitochondria and microfilament were demonstrated. Plasma cells were either clustered in the interstitial spaces in groups of 3 to 4 cells or singly scattered.

III.4.D. The Deep Gland

The secretory cells showed a variable amount of electron dense granules in the apical cytoplasm. The most common granules were round to oval, and usually homogenous in texture and membrane bound (Figs. 70 and 71). These granules were located adjacent to the Golgi apparatus.

The nuclei of the secretory cells were round to oval in shape with variable indentations and they usually occupied the basal cytoplasm and possessed heterochromatin mainly adjacent to the inner nuclear membrane (Figs. 70 and 71).

Abundant rough endoplasmic reticulum and moderate number of rod -shaped mitochondria were observed in the basal cytoplasm and in the perinuclear area. The rough endoplasmic reticulum was composed of parallel flattened lamellae (Fig. 70) which were heavily studded with ribosomes .

In the supranuclear region, semicircularly arranged parallel cisternae of Golgi apparatus were seen .They were highly developed .

The apical surface of each secretory cell possessed slender microvilli of variable length projecting into the lumen of the secretory end-pieces. Merocrine exocytosis of the secretory substance through the apical surface of the secretory cells was demonstrated.

Clustered or individually scattered large lipid droplets were found throughout the basal cytoplasm of the secretory cells. The content of the lipid droplets was mostly homogenous in appearance (Fig. 70). An

area of homogenous dense substance was observed connecting two lipid droplets.

The lateral apical cell borders of the secretory cells were straight, while at the lateral basal parts, were folded. The lateral cell border of adjacent cells were attached together with apical junctional complex, consisting of zonula occludens, zonula adherens and a macula adherens (desmosomes).

The basal cell membrane was either smooth or folded and rested either on myoepithelial cells with desmosomal attachments or on a thin basal lamina with hemidesmosomal attachments.

The myoepithelial cells encircled the secretory cells. They were situated between the basal border of the secretory cells and the basal lamina. They appeared as slender, spindle-shaped or stellate cells. Their nuclei were usually oval and fairly smooth in outline. In the cytoplasm, a few mitochondria, many bundles of microfilaments and scattered focal electron dense granules were seen. Each myoepithelial cell was differentiated into a cell body and cytoplasmic processes. The cell body was large, oval or triangular in shape and contained oval or slightly elongated nucleus. The cytoplasmic processes of myoepithelial cells were slender in shape.

The epithelial cells of the duct were short and the nuclei were horizontally arranged and they contained secretory granules when they joined the secretory cells (Fig. 72). The epithelial cells of the ducts contained numerous, small and round mitochondria (Fig. 72) which were surrounded by a network of rough endoplasmic reticulum.

Melanin granules with either a regular or irregular shape were found in the cytoplasm of the epithelial cells (Fig. 72). Junctional complexes were found between the upper lateral plasma membranes of

adjacent epithelial cells of the duct. Desmosomes attached the epithelial cells of the duct to the myoepithelial cells.

A thin basal lamina en-sheathed the epithelial cells of the duct (Fig. 72). Numerous pigmented cells were observed within interstitial connective tissue (Fig. 73). The luminal border of the epithelial cells of the duct possessed short, rounded and widely spaced microvilli (Fig. 72) supported by microfilaments orientated parallel to their long axis. Rod-shaped crystalline inclusions were observed within the epithelial cells of the duct.

Many large goblet cells were found between the epithelial cells of the duct. Some goblet cells contained both light and dark mucigenous granules. The luminal surface of the goblet cells usually contained a few microvilli. Numerous goblet cells were seen discharging their mucous granules into the lumen. They occupied the basal cytoplasm of the epithelial cells of the duct.

Nerve terminals penetrated the basal lamina of the glandular endpieces and they were located between the secretory cells and the myoepithelial cells. These terminals contained mitochondria, a few number of electron dense granules and many small clear vesicles.

III.5. Morphometry

The morphometric analysis was carried out on six superficial glands and six deep glands of the third eyelid (six of them were from the right side and the other six were from the left side).

III.5.A. The superficial Gland of the Third Eyelid

The study revealed that there were no differences in the morphometric results between the right and left glands in the camel. The results of the morphometric analysis were presented in the tables 2-13.

The mean absolute volume of the fresh right gland was about 1.8 $cm.^3 \pm 0.27$, while that of the left gland was 1.26 $cm.^3 \pm 0.64$.

In the right superficial gland, the glandular tissue amounted to about 65.20% of the total volume of the gland, the connective tissue, which included the capsule and trabeculae, constituted about 27.93% of the total volume of the gland, while the main and interlobular ducts gave a value of about 4.77% of the total volume of the gland and the hair follicles occupied only 2.09% of the total volume of the gland. The absolute volume was 1.17 $cm.^3$ for glandular tissue and 0.05 $cm.^3$ for connective tissue (table 9).

In the left superficial gland, the glandular tissue amounted to about 63.83% of the total volume of the gland, the connective tissue 29.78% of the total volume of the gland, the main and interlobular ducts gave a value of about 4.51% of the total volume of the gland and the hair follicles occupied only 1.88% of the total volume of the gland. The absolute volume was 0.80 $cm.^3$ for glandular tissue and 0.38 $cm.^3$ for connective tissue (table 10).

Table (2): A table showing the data obtained by point counting fields of a sample section of the right superficial gland of the third eyelid.

F.No.	G.T	C.T	H.F	D	Total
1	86	29	6	….	121
2	75	37	5	4	121
3	50	61	4	6	121

4	88	16	4	13	121
5	102	12	4	3	121
6	82	34	5	….	121
7	88	19	2	12	121
8	96	16	4	5	121
9	95	17	3	6	121
10	90	17	2	12	121
11	92	20	1	8	121
12	34	87	….	….	121
13	95	12	5	9	121
14	94	11	6	10	121
15	92	21	2	6	121
16	75	25	5	16	121
17	89	28	4	….	121
18	85	6	4	26	121
19	85	34	2	….	121
20	96	25	….	….	121
21	21	100	….	„„	121
22	95	10	4	12	121
23	78	10	4	29	121
24	106	12	….	3	121
25	55	66	….	….	121
26	83	35	….	3	121
27	102	19	….	….	121
28	77	44	….	….	121
29	56	61	4	….	121
30	91	30	….	….	121
Total	2453	914	80	183	3630

G.T. = Glandular tissue
C.T. = Connective tissue
H.F. = Hair follicle
D. = Interlobular and main ducts

Table (3): Animal No 1 (right side). The total points counted, the volume fraction and absolute volume of each component of the right superficial gland of the third eyelid.

Section No.	G.T.	C.T.	H.F.	D.	Total
1	2484	896	63	187	3630

2	2278	1108	83	161	3630
3	2315	1041	96	178	3630
4	2369	1010	69	182	3630
Total	9446	4055	311	708	14520
Vv.	65.05%	27.93%	2.14%	4.88%	100%
Abs. V.	1.30 $cm.^3$	0.56 $cm.^3$	0.04 $cm.^3$	0.10 $cm.^3$	2.00 $cm.^3$

Table (4): Animal No 2 (right side). The total points counted, the volume fraction and absolute volume of each component of the right superficial gland of the third eyelid.

Section No.	G.T.	C.T.	H.F.	D.	Total
1	2453	914	80	183	3630
2	2184	1222	75	149	3630
3	2600	834	83	113	3630
4	2420	927	75	208	3630
Total	9657	3897	313	653	14520
Vv.	66.51%	26.84%	2.15%	4.50%	100%
Abs. V.	0.99 $cm.^3$	0.40 $cm.^3$	0.03 $cm.^3$	0.08 $cm.^3$	1.50 $cm.^3$

G.T. = Glandular tissue
C.T. = Connective tissue
H.F. = Hair follicle
D. = Interlobular and main ducts
Vv. = Volume fraction
Abs.V. = Absolute volume

Table (5): Animal No 3 (right side). The total points counted, the volume fraction and absolute volume of each component of the right superficial gland of the third eyelid.

Section No.	G.T.	C.T.	H.F.	D.	Total
1	2129	1290	24	187	3630
2	2423	1007	69	131	3630

3	2259	1117	118	136	3630
4	2488	803	78	261	3630
Total	9299	4217	289	715	14520
Vv.	64.04%	29.04%	1.99%	4.93%	100%
Abs. V.	1.22 $cm.^3$	0.55 $cm.^3$	0.04 $cm.^3$	0.09 $cm.^3$	1.90 $cm.^3$

Table (6): Animal No 1 (left side). The total points counted, the volume fraction and absolute volume of each component of the left superficial gland of the third eyelid.

Section No.	G.T.	C.T.	H.F.	D.	Total
1	2320	1047	94	169	3630
2	2369	1059	88	114	3630
3	2287	1127	66	150	3630
4	2166	1303	31	130	3630
Total	9142	4536	279	563	14520
Vv.	62.96%	31.24%	1.92%	3.88%	100%
Abs. V.	1.01 $cm.^3$	0.50 $cm.^3$	0.03 $cm.^3$	0.06 $cm.^3$	1.60 $cm.^3$

G.T. = Glandular tissue
C.T. = Connective tissue
H.F. = Hair follicle
D. = Interlobular and main ducts
Vv. = Volume fraction
Abs.V. = Absolute volume

Table (7): Animal No 2 (left side). The total points counted, the volume fraction and absolute volume of each component of the left superficial gland of the third eyelid.

Section No.	G.T.	C.T.	H.F.	D.	Total
1	2338	1159	38	95	3630
2	2149	1293	53	135	3630

3	2401	907	93	229	3630
4	2378	1064	86	102	3630
Total	9266	4423	270	561	14520
Vv.	63.82%	30.46%	1.86%	3.86%	100%
Abs. V.	0.76 $cm.^3$	0.36 $cm.^3$	0.02 $cm.^3$	0.05 $cm.^3$	1.20 $cm.^3$

Table (8): Animal No 3 (left side). The total points counted, the volume fraction and absolute volume of each component of the left superficial gland of the third eyelid.

Section No.	G.T.	C.T.	H.F.	D.	Total
1	2513	861	76	180	3630
2	2110	1221	63	236	3630
3	2476	760	84	310	3630
4	2293	1172	48	117	3630
Total	9392	4014	271	843	14520
Vv.	64.68%	27.64%	1.87%	5.80%	100%
Abs. V.	0.64 $cm.^3$	0.28 $cm.^3$	0.02 $cm.^3$	0.06 $cm.^3$	1.00 $cm.^3$

G.T. = Glandular tissue
C.T. = Connective tissue
H.F. = Hair follicle
D. = Interlobular and main ducts
Vv. = Volume fraction
Abs.V. = Absolute volume

Table (9): The absolute volume and standard deviation of each component of the right superficial glands of the third eyelid and their mean values.

Animal No.	G.T. Abs.V. $cm.^3$	C.T. Abs.V. $cm.^3$	H.F. Abs.V. $cm.^3$	D. Abs.V. $cm.^3$	Total Abs.V. $cm.^3$

1	1.30	0.56	0.04	0.10	2.00
2	0.99	0.40	0.03	0.08	1.50
3	1.22	0.55	0.04	0.09	1.90
Total	3.51	1.51	0.11	0.27	5.40
Mean	1.17	0.50	0.04	0.09	1.80
S.D.	0.16	0.09	0.01	0.01	0.27

Table (10): The absolute volume and standard deviation of each component of the left superficial glands of the third eyelid and their mean values.

Animal No.	**GT Abs.V. $cm.^3$**	**CT Abs.V. $cm.^3$**	**HF Abs.V. $cm.^3$**	**D. Abs.V. $cm.^3$**	**Total Abs.V. $cm.^3$**
1	1.01	0.50	0.03	0.06	1.60
2	0.76	0.36	0.02	0.05	1.19
3	0.64	0.28	0.02	0.06	1.00
Total	2.41	1.14	0.07	0.17	3.79
Mean	0.80	0.38	0.02	0.06	1.26
S.D	0.19	0.11	0.01	0.01	0.31

G.T. = Glandular tissue
C.T. = Connective tissue
H.F. = Hair follicle
D. = Interlobular and main ducts
Abs.V. = Absolute volume
S.D. = Standard Deviation

Table (11): The volume fraction and standard deviation of each component of the right superficial glands of the third eyelid and their mean values.

Animal No.	**G.T. (Vv.)%**	**C.T. (Vv.)%**	**H.F. (Vv.)%**	**D. (Vv.)%**	**Total**
1	65.05	27.93	2.14	4.88	100

2	66.51	26.84	2.15	4.50	100
3	64.04	29.04	1.99	4.93	100
Total	195.60	83.81	6.28	14.31	300
Mean	65.20	27.94	2.09	4.77	100
S.D.	1.24	1.10	0.09	0.24	

Table (12): The volume fraction and standard deviation of each component of the left superficial glands of the third eyelid and their mean values.

Animal No.	G.T. (Vv.)%	C.T. (Vv.)%	H.F. (Vv.)%	D. (Vv.)%	Total
1	62.96	31.24	1.92	3.88	100
2	63.82	30.46	1.86	3.86	100
3	64.68	27.64	1.87	5.80	100
Total	191.46	89.34	5.65	13.54	300
Mean	63.82	29.78	1.88	4.51	100
S.D.	0.86	1.89	0.03	1.11	

G.T. = Glandular tissue
C.T. = Connective tissue
H.F. = Hair follicle
D. = Interlobular and main ducts
Vv. = Volume fraction
S.D. = Standard Deviation

Table (13): Showing the volume (Vv.) and the mean absolute volume of components of the right and left superficial gland of the third eyelid:

Site of gland	G.T.		C.T.		H.F.		D.		Total
	%	cm^3	%	cm^3	%	cm^3	%	cm^3	cm^3
Right	65.20 ± 1.24	1.17 ± 0.16	27.93 ± 1.10	0.50 ± 0.09	2.09 ± 0.09	0.04 ± 0.01	4.77 ± 0.24	0.09 ± 0.01	1.80 ± 0.27
Left	63.82 ± 0.86	0.80 ± 0.41	29.78 ± 1.89	0.38 ± 0.19	1.88 ± 0.03	0.02 ± 0.01	4.51 ± 1.11	0.06 ± 0.03	1.26 ± 0.64

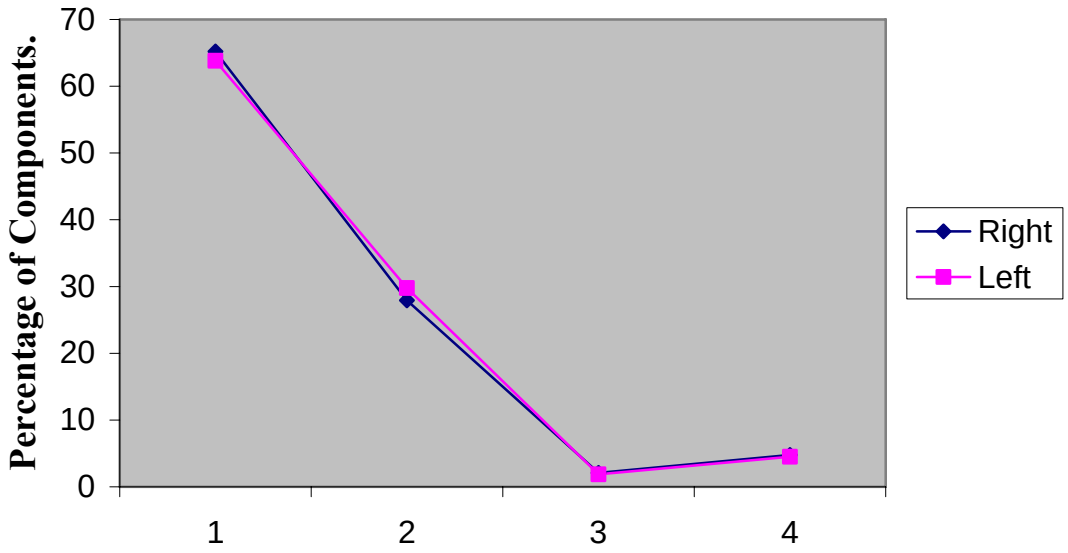
G.T. = Glandular tissue

C.T. = Connective tissue

H.F. = Hair follicle

D. = Interlobular and main ducts

Fig.(I): The Volume Fraction of the Components of the Right and Left Superficial Glands of the Third Eyelid.



1. Glandular tissue
2. Connective tissue
3. Hair follicle
4. Interlobular and main ducts

III.5.B. The Deep Gland of the Third Eyelid

The analysis revealed that the connective tissue, which included the capsule, trabeculae and cartilage, constituted 24.45% (0.59 $cm.^3 \pm$ 0.03) of the volume of the right gland and 22.30% (0.50 $cm.^3 \pm$ 0.04) of the volume of the left gland. The glandular tissue of the right gland constituted 65.18% (1.58 $cm.^3 \pm 0.14$) and in the left gland it constituted 67.46% (1.64 $cm.^3 \pm$ 0.12). The main and interlobular ducts constituted 10.42% (0.26 $cm.^3 \pm 0.04$) in the right gland and 10.34% (0.29 $cm.^3 \pm$ 0.08) in the left gland.

The mean absolute volume of the fresh right gland was about 2.43 $cm.^3 \pm 0.21$, while that of the left gland was 2.43 $cm.^3 \pm 0.23$.

Tables (14-24) show the results of the morphometric analysis of the right and left deep glands of the third eyelid of the dromedary.

Table (14): A table showing the data obtained by point counting fields of a sample section of the right deep gland of the third eyelid.

F.N	G.T.	C.T.	D.	Total
1	65	40	16	121
2	81	17	23	121
3	15	50	56	121
4	106	15	…	121
5	116	5	….	121
6	99	22	….	121
7	11	47	63	121
8	102	19	….	121
9	113	8	….	121
10	110	11	….	121
11	90	22	9	121
12	51	32	38	121
13	108	13	….	121
14	99	10	12	121
15	116	5	….	121
16	111	10	….	121
17	67	39	15	121
18	101	20	….	121
19	107	5	9	121
20	112	9	….	121
Total	1780	399	241	2420

G.T. = Glandular tissue

C.T. = Connective tissue

D. = Interlobular and main ducts

Table (15): Animal No 1 (right side). The total points counted, the volume fraction and absolute volume of each component of the right deep gland of the third eyelid.

Section No.	G.T.	C.T.	D.	Total
1	1601	659	160	2420
2	1484	639	297	2420
3	1667	500	253	2420
4	1572	601	247	2420
Total	6324	2399	957	9680
Vv.	65.33%	24.78%	9.89%	100%
Abs. V.	1.63 $cm.^3$	0.62 $cm.^3$	0.25 $cm.^3$	2.50 $cm.^3$

Table (16): Animal No 2 (right side). The total points counted, the volume fraction and absolute volume of each component of the right deep gland of the third eyelid.

Section No.	G.T.	C.T.	D.	Total
1	1488	679	253	2420
2	1669	579	172	2420
3	1839	452	129	2420
4	1279	743	398	2420
Total	6275	2453	952	9680
Vv.	64.83%	25.34%	9.88%	100%
Abs. V.	1.42 $cm.^3$	0.56 $cm.^3$	0.22 $cm.^3$	2.20 $cm.^3$

G.T. = Glandular tissue
C.T. = Connective tissue
D. = Interlobular and main ducts
Vv. = Volume fraction
Abs.V. = Absolute volume

Table (17): Animal No 3 (right side). The total points counted, the volume fraction and absolute volume of each component of the right deep gland of the third eyelid.

Section No.	G.T.	C.T.	D.	Total
1	1592	508	320	2420
2	1454	454	512	2420
3	1675	622	123	2420
4	1607	665	148	2420
Total	6328	2249	1103	9680
Vv.	65.37%	23.23%	11.39%	100%
Abs. V.	1.69 $cm.^3$	0.60 $cm.^3$	0.30 $cm.^3$	2.60 $cm.^3$

Table (18): Animal No 1 (left side). The total points counted, the volume fraction and absolute volume of each component of the left deep gland of the third eyelid.

Section No.	G.T.	C.T.	D.	Total
1	1436	627	357	2420
2	1780	399	241	2420
3	1344	826	250	2420
4	1839	480	101	2420
Total	6399	2332	949	9680
Vv.	66.11%	24.40%	9.80%	100%
Abs. V.	1.65 $cm.^3$	0.49 $cm.^3$	0.36 $cm.^3$	2.50 $cm.^3$

G.T. = Glandular tissue
C.T. = Connective tissue
D. = Interlobular and main ducts
Vv. = Volume fraction
Abs.V. = Absolute volume

Table (19): Animal No 2 (left side). The total points counted, the volume fraction and absolute volume of each component of the left deep gland of the third eyelid.

Section No.	G.T.	C.T.	D.	Total
1	1890	230	300	2420
2	1667	538	215	2420
3	1380	805	235	2420
4	1725	517	178	2420
Total	6662	2090	928	9680
Vv.	68.82%	21.59%	9.59%	100%
Abs. V.	1.51 $cm.^3$	0.47 $cm.^3$	0.21 $cm.^3$	2.20 $cm.^3$

Table (20): Animal No 3 (left side). The total points counted, the volume fraction and absolute volume of each component of the left deep gland of the third eyelid.

Section No.	G.T.	C.T.	D.	Total
1	1485	890	45	2420
2	1723	298	399	2420
3	1612	127	681	2420
4	1710	710	0	2420
Total	6530	2025	1125	9680
Vv.	67.46%	20.92%	11.62%	100%
Abs. V.	1.75 $cm.^3$	0.54 $cm.^3$	0.30 $cm.^3$	2.60 $cm.^3$

G.T. = Glandular tissue
C.T. = Connective tissue
D. = Interlobular and main ducts
Vv. = Volume fraction
Abs.V = Absolute volume

Table (21): The absolute volume and standard deviation of each component of the right deep glands of the third eyelid and their mean values.

Animal No.	G.T. Abs.V. $cm.^3$	C.T. Abs.V. $cm.^3$	D. Abs.V. $cm.^3$	Total Abs.V. $cm.^3$
1	1.63	0.62	0.25	2.50
2	1.42	0.56	0.22	2.20
3	1.69	0.60	0.30	2.59
Total	4.74	1.78	0.77	7.29
Mean	1.58	0.59	0.26	2.43
S.D.	0.14	0.03	0.04	0.21

Table (22): The absolute volume and standard deviation of each component of the left deep glands of the third eyelid and their mean values.

Animal No.	G.T. Abs.V. $cm.^3$	C.T. Abs.V. $cm.^3$	D. Abs.V. $cm.^3$	Total Abs.V. $cm.^3$
1	1.65	0.49	0.36	2.50
2	1.51	0.47	0.21	2.19
3	1.75	0.54	0.30	2.59
Total	4.91	1.50	0.87	7.28
Mean	1.64	0.50	0.29	2.43
S.D.	0.12	0.04	0.08	0.23

G.T. = Glandular tissue
C.T. = Connective tissue
D. = Interlobular and main ducts
Abs.V. = Absolute volume
S.D. = Standard Deviation

Table (23): The volume fraction and standard deviation of each component of the right deep glands of the third eyelid and their mean values.

Animal No.	G.T. (Vv.)%	C.T. (Vv.)%	D. (Vv.)%	Total
1	65.33	24.78	9.98	100
2	64.83	25.34	9.88	100
3	65.37	23.23	11.39	100
Total	195.53	73.35	31.25	300
Mean	65.18	24.45	10.42	100
S.D.	0.30	1.09	0.84	

Table (24): The volume fraction and standard deviation of each component of the left deep glands of the third eyelid and their mean values.

Animal No.	G.T. (Vv.)%	C.T. (Vv.)%	D. (Vv.)%	Total
1	66.11	24.40	9.80	100
2	68.82	21.59	9.59	100
3	67.46	20.92	11.62	100
Total	202.39	66.91	31.01	300
Mean	67.46	22.30	10.34	100
S.D.	1.36	1.85	1.12	

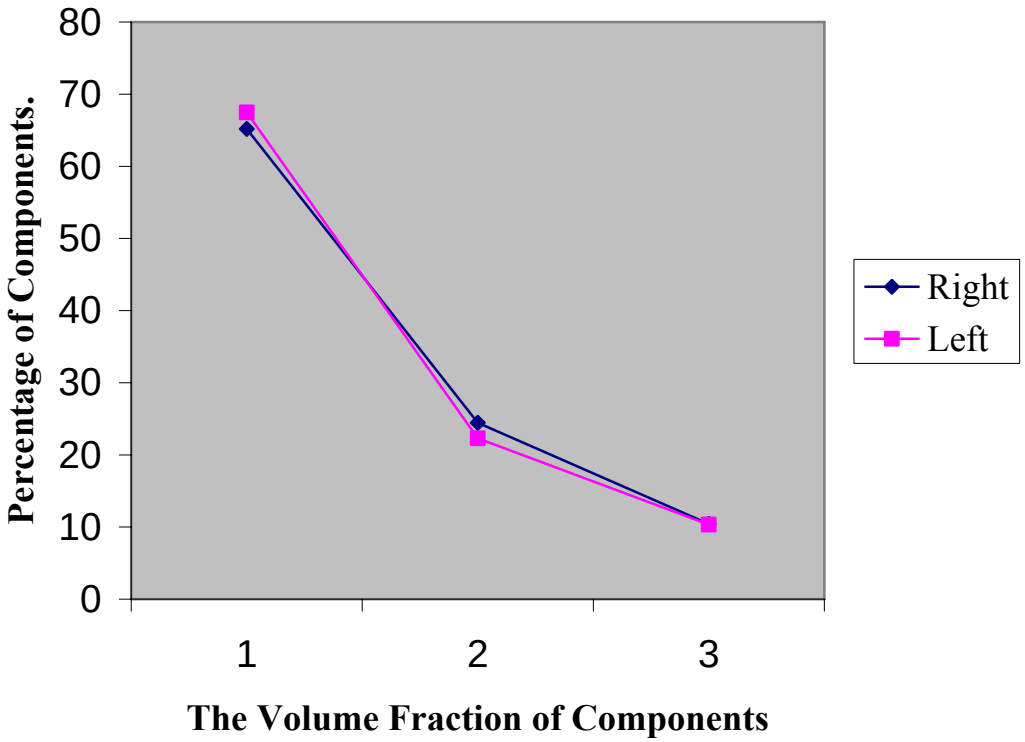
G.T. = Glandular tissue
C.T. = Connective tissue
D. = Interlobular and main ducts
Vv. = Volume fraction
S.D. = Standard Deviation
Table Sum

Table (24): Showing the volume (Vv.) and the mean absolute volume of components of the right and left deep gland of the third eyelid:

Site of gland	G.T.		C.T.		D.		Total
	%	cm3	%	cm3	%	cm3	cm3
Right	65.18 + 0.30	1.58 + 0.14	24.45 + 1.09	0.59 + 0.03	10.42 + 0.84	0.26 + 0.04	2.43 + 0.21
Left	67.46 + 1.36	1.64 + 0.12	22.30 + 1.85	0.50 + 0.04	10.34 + 1.12	0.29 + 0.08	2.43 + 0.23

G.T. = Glandular tissue
C.T. = Connective tissue
D. = Interlobular and main ducts

Fig. (II): The Volume Fraction of Components of the Right and Left Deep Glands of the Third Eyelid.



1. Glandular tissue
2. Connective tissue
3. Interlobular and main ducts

CHAPTER FOUR
DISCUSSION

CHAPTER FOUR
DISCUSSION

IV.1.Gross Anatomy

IV.1.1. Position and Topography of the Eyeball

In the present investigation, the eyeballs of the dromedary camel entirely were large and are totally directed towards the lateral side of the orbital cavity. A similar finding has already been reported in the same species (Tayeb, 1962; Ibrahim, 1990)

IV.1.2. Weight and Dimensions of the eyeball

In the present study the eyeball of the camel weighs about 36.2 g. and measures about 3.7 cm in length and about 4.1 cm in width. The cornea measures about 2.5 cm in length and about 2.0 cm in width. Symthe (1958) reported that the dimensions of the eyeball of the camel are 4.5 cm in length and 4.0 cm in width. Moreover, Rahi ***et al.*** (1980) stated that the eyeball of the camel is about 3.5 cm in length and 3.1 cm in width and the cornea is about 2.5 cm in length and 1.7 cm in width. The controversy in these reported measurements may be explained by differences in the age and breed of the animals studied.

IV.1.3. The Eyelids and Conjunctiva

In the present investigation, the medial margin of the camel eyelids, possesses a triangular hairy area. A similar observation has been documented in the same species by Tayeb (1962).

The present study supports the findings of Ibrahim (1990) that darkly pigmented areas are observed in several horizontal lines on the caudal half of the conjunctival part and these represented subconjunctival lymph nodules.

IV.1.4. The Eyelashes

The eyelashes are long, strong and densely arranged at the margins of the eyelids of the camel (Tayeb, 1962). This is in agreement with the

present study. These long, strong and densely arranged eyelashes are important to an animal like the camel which inhabits dry and sandy lands.

IV.1.5. The Third Eyelid

In the present study, the third eyelid is situated on the rostromedial aspect of the eyeball and it is quadrilateral in outline. It measures about 3.8 cm in length and 2.04 cm in width. These results are identical with those of Ibrahim (1990) in the same species.

The results of this study are similar to the findings in other domestic mammals of Diesem (1975) that the superficial part of the third eyelid possesses dark pigmentation at the free margin. Moreover, the results of this study are in agreement with the findings of Ibrahim (1990) in the fact that another dark pigmentation appears at the line of reflection of the conjunctiva onto the superficial gland of the third eyelid especially in old camels.

IV.1.6. The Glands of the Third Eyelid

According to the present study, it is evident that the glands of the third eyelid are similar to those described in the camel by Fahmy et al. (1971), Sayed (1988), Ibrahim (1990), Fateh el Bab ***et al***. (1991), Nagpal ***et al.*** (1991) and Hifny and Aly (2006) and in the pig (Diesem, 1975). However, these glands differ from those described in other domestic mammals by Bradley (1947, 1948), Symthe (1958), Dyce and Wensing (1971), Diesem (1975), Das (1979), Martin ***et al.*** (1988), Ibrahim (1990) and Abou-Elmaged (1997).

Fahmy ***et al***. (1971), Ibrahim (1990), Fateh el Bab ***et al***. (1991), Nagpal ***et al***. (1991) and Hifny and Aly (2006) reported that the superficial gland consists of numerous lobules of different sizes and shapes scattered adjacent to the base of the third eyelid. It is triangular in shape, flat and bright rosey red in colour. The results of the present study are in agreement with these findings.

In the present study, the superficial gland measures about 3.40 cm. in length, 2.10 cm. in width, 0.55 cm. in thickness and 4.20 cm. in circumference.

The deep gland of the third eyelid is either pinkish in colour (Symthe, 1958) or reddish in colour (Bradley, 1948; Fahmy ***et al***., 1971)). The present study confirms the findings of Ibrahim (1990) that the deep gland possesses a brown colour. Fahmy ***et al.*** (1971) reported that the deep gland is compact and oval in outline. The presence of some pigmented streaks at the caudal end of the main ducts of the deep gland is reported in the camel by Fahmy ***et al.*** (1971) and Ibrahim (1990). Similar findings are found in the present study.

IV.2. Histology

IV.2.A. Eyeball

IV.2.A.1. Fibrous Tunic

The results of this study confirm the findings of Rahi ***et al***. (1980) and Bareedy ***et al.*** (1986), Trautmann and Fiebiger (1957), Dellmann and Brown (1981) and Slatter (2001) that the sclera is composed of a dense irregular connective tissue consisting mainly of large bundles of collagen fibres and fibroblast between the bundles in some mammals including the camel. Also the results of this study are in agreement with the findings of Rahi ***et al.*** (1980) and Bareedy ***et al.*** (1986) that numerous pigment cells and small blood vessels are observed within the bundles of collagen fibres of the sclera of the camel.

In the ox, buffalo, goat and donkey (Prince ***et al.***, 1960), bundles of smooth muscle fibres are observed in the deep part of the sclera but in the present study, there is no evidence of the presence of these bundles.

The results of Rahi ***et al.*** (1980) and Bareedy ***et al.*** (1986) showed that the cornea of the camel is small, transparent and forms the anterior segment of the eyeball. This is also true in the present study. The major function of the cornea is to permit the rays of the light to enter the eyeball (Ehlers, 1970).

The anterior surface of the cornea of the camel in the present study is covered by stratified squamous epithelium. The epithelium consists of 10-12 layers of non-keratinized cells. The cells of the epithelium are subdivided into three layers: a basal, intermediate and superficial layers. These results are in agreement with those of Rahi ***et al.*** (1980) and Bareedy ***et al.*** (1986) in the same species. The present study confirms the earliar report of Ehlers (1970) in the ox, dog, pig, cat, rabbit and rat.

The present investigations support the finding of Rahi ***et al.*** (1980) in the camel and Gelatt (1991) in mammals that, at the limbus, the epithelium is highly pigmented due to the presence of large branching pigment cells. The pigmented cells are scattered in all layers except the superficial layer.

In the present investigations, Bowman's membrane of the cornea of the camel is absent. A similar finding has already been reported in the camel (Rahi ***et al.***, 1980; Bareedy ***et al.***, 1986), pig (Diesem, 1975; Gelatt, 1991), dog (Shively and Epling, 1970) and mice (Whitear, 1960).

In the present investigations, Descemet's membrane of the cornea of the camel is a highly thick, glassy and homogenous basement membrane. This finding confirmed the results of Rahi ***et al.*** (1980), Bareedy ***et al.*** (1986) and Prince ***et al.*** (1960) in the camel and the horse respectively. Prince ***et al.*** (1960) observed a strong P.A.S reaction in Descemet's membrane of the cornea of the horse. A similar observation is also noted in the present study. Talford and Bridgeman (1995) suggested that Descemet's membrane may be used as a pump for water and ions.

In the camel (Rahi ***et al.***, 1980, Bareedy ***et al.***, 1986), some mammals (Banks, 1993, Eighth ***et al.***, .1997, Slatter, 2001) and man (Junqueira ***et al.***, 1998) the endothelium of the cornea consisted of flat or low cubodial cells. This is also true in the present study. Slatter (2001) suggested that in case of penetrating wounds of the cornea, these cells probably secrete new Descemet's membrane.

IV.2.A.2. Vascular Tunic

In the present investigation, the suprachoroid layer is composed of dense irregular connective tissue consisting mainly of small bundles of collagen fibres. A large number of branched pigmented cells of irregular shape are scattered within connective tissue. These results are identical with those of Rahi ***et al.*** (1980), Bareedy ***et al.*** (1986) and Kotb (2006) in the same species, and also with those of Banks (1993) in some mammals and Kotb (2006) in the donkey, buffalo and dog.

It appears from the present study that the structure of the vascular layer of the choroid of the camel is similar to that presented by Rahi ***et al.*** (1980), Bareedy ***et al.*** (1986), Kotb (2006). The present study also

supports the findings of Kotb (2006) that the stroma of the choroid contains irregular smooth muscle fibres.

The tapetal layer of the choroid is absent in the monkey (Symthe, 1958); man (Leeson and Leeson, 1970; Amenta, 1978), pig (Diesem, 1975; Gelatt, 1991; Banks, 1993); and camel (Rahi ***et al.***, 1980; Bareedy ***et al.***, 1986). However, Kotb (2006) suggested that the presence of fine bundles of collagen fibres may be considered as a tapetal layer of the choroid of the camel.

According to the investigations of Rahi ***et al.*** (1980), Bareedy ***et al.*** (1986) in the camel and McMinn (1994) in some mammals, the choriocapillary layer of the choroid is composed of a dense network of capillaries within loose connective tissue. The present study confirms these findings except that melanocytes are observed within loose connective tissue in this study.

Diesem (1975), Rahi ***et al.*** (1980), Fawcett and Jensh (2002), and Kotb (2006) stated that the ciliary body is a direct continuation of the choroid and it consists of the ciliary epithelium, ciliary stroma, ciliary muscle and ciliary processes and the ciliary body is extends deep into the iris.

The present study supports the findings of Rahi ***et al.*** (1980) and Kotb (2006) that the ciliary epithelium of the camel consists of two layers of epithelial cells: pigmented and non-pigmented cells.

The present study supports the findings of Banks (1993), Bacha and Bacha (2000) Slatter (2001), Kotb (2006) that, the ciliary processes consist of a central stromal core of vascular loose connective tissue which is covered by a ciliary epithelium.

The present study shows that the vascular tunic of the camel possesses a well developed ciliary body with numerous ciliary processes that may indicate a wide surface area of the ciliary epithelium. This

presumption is supported by the high volume percentage of aqueous humor in the eyeball of the camel.

Rahi ***et al.*** (1980) and Ktob (2006) showed that the iris of the camel is heavily pigmented and is covered by a layer of pigmented epithelium at the anterior and posterior surfaces. The stroma is composed of small bundles of collagen fibres, numerous small blood vessels, branched pigmented cells and sphincter and dilator muscles. The present study confirms the findings of the above mentioned authors. The major function of the iris is to regulate the amount of light entering the eyeball (Tortora and Anagnostakos, 1981). This function is certainly not facilitated by the weak dilator muscle in combination with a relatively strong sphincter muscle. Therefore, the camel iris seems to be suitable for the bright environment of the camels habitat.

The presence of the iris granules has been observed in the horse (Dellmann and Brown, 1981), sheep, goat (Banks, 1993), buffalo, donkey and dog (2006). It is also well represented in the ventral and dorsal pupillary margins of the iris of the camel (Rahi ***et al.***, 1980; Kotb, 2006) and this is also the case in the present study. Moreover, Rahi ***et al.*** (1980) are of the opinion that these granules may be interlocked during miosis and thus diminish glare during daylight.

IV.2.A.3. Nervous Tunic

Trautmann and Fiebiger (1957), Diesem (1975) Dellmann and Brown (1981), Eighth ***et al.*** (1997), Junquerira ***et al.*** (1998), Bacha and Bacha (2000), Slatter (2001) and Fawcett and Jensh (2002) agreed that the structure of the retina in many mammals is divided into ten layers. In the camel, the retina could also be divided into ten layers (Rahi ***et al.***, 1980). The results of the present investigation are in agreement with these findings.

IV.2.B. The Appendages of the Eyeball

IV.2.B.1. The Eyelids

The presence of a large number of sweat glands in the subepithelial layer of the eyelids in the present study confirmed earliar reports in the camel (Lee and Schmidt-Nielson, 1962, Dowling and Nay, 1962, Ibrahim, 1990), horse (Talukdar ***et al.***, 1970a), buffalo (Hifny ***et al.***, 1985) and dog (Nielsen, 1953; Lovall and Getty, 1957).

In domestic mammals, the sinus hair follicles are situated at the base of the upper eyelid (Trautmann and Fiebiger, 1957; Dyce ***et al.***, 1987), while in the horse, they are scattered only over the lower part of the lower eyelid (Diesem, 1975). In the present study, they are well represented in both lower and upper eyelids and they are well developed and consist of five layers. Prince ***et al.*** (1960) and Hifny ***et al.*** (1985) reported that arrector pili muscles are associated with the sinus hair follicles in the horse and buffalo respectively. In the present study, there is no evidence of arrector pili muscle in the camel. Schmidt-Nielsen, Schmidt-Nielsen, Jarnum and Houpt (1957) are of the opinion that the presence of a large number of sinus hair follicles in the camel provides an efficient barrier against heat gain from the environment.

Tarsal glands are well represented in the upper eyelid of the camel (Fahmy ***et al.***, 1971), horse, ox, sheep, goat, (Prince ***et al.***, 1960), buffalo, donkey (Ibrahim, 1990), dog, cat (Diesem, 1975) and pig (Gellatt, 1991). The present results support the findings of Lee and Schmidt-Nielson (1962), Ibrahim (1990) and Zayed (2006) that the tarsal glands are absent in the camel.

IV.2.B.2. The Conjunctiva

The present investigation showed that the conjunctiva is lined with several layers of stratified squamous epithelium with large goblet cells.

Numerous blood vessels, lymphocytes and lymph nodules are observed within the subepithelial layer. These results are in agreement with the findings of Ibrahim (1990) and Nagpal ***et al.*** (1991) in the camel.

The present investigation disagreed with the findings of Dellmann and Brown (1981) in the ox, sheep and goat, in which the conjunctiva is lined by transitional epithelium with large goblet, and Banks (1993) who stated that the conjunctiva is lined by pseudostratified epithelium with large goblet cells in the horse, dog and cat.

IV.2.B.3. The Third Eyelid

Ellenberger and Baum (1943), Diesem (1975), Nagpal ***et al.*** (1991), Banks (1993) and Render (2001) stated that the lamina propria of the third eyelid possesses a hyaline cartilaginous plate in ruminants, dog, horse, pig, camel and rabbit respectively. However, in the horse and pig (Ellenberger and Baum, 1943; Banks, 1993), cat (Banks, 1993) and camel (Fahmy ***et al.***, 1971) the cartilaginous plate is elastic in nature.

In the present study, several platelets of hyaline cartilage are present within the lamina propria of the third eyelid of the camel. They are encapsulated within a perichondrium. These findings confirm the results of Ibrahim (1990) and Nagpal ***et al.*** (1991) in the same species.

The presence of a large number of lymphocytes and lymphatic nodules in the lamina propria of the third eyelid has been observed in the ox, sheep, horse, dog, cat, pig (Banks, 1993), buffalo (Das, 1979), rabbit Render (2001) and camel (Ibrahim, 1990; Hifny and Aly, 2006). This is also true in the present investigation. These findings indicated that the third eyelid of the camel may play an important role in the defense mechanism of the eye. Slatter (2001) is of the opinion that the direct contact of the corneal ulcer with these lymphatic tissues aids in corneal protection and is essential in its healing.

IV.2.B.4. The Glands of the Third Eyelid

In the present investigation, the superficial gland of the third eyelid of the camel is covered by thick capsule of dense bundles of collagenous fibres with a few reticular and elastic fibres. The outer surface of the capsule is covered by stratified squamous epithelium with large goblet cells. There are trabeculae that extend from the inner surface of the capsule and divide the gland into many lobules. The trabeculae have the same components of the capsule. These results are identical with those of Fahmy ***et al.*** (1971) and Ibrahim (1990) in the same species.

Fahmy ***et al.*** (1971) and Ibrahim (1990) stated that the superficial gland of the third eyelid in the camel is sebaceous in nature. On the other hand, Banks (1993) reported that it is seromucous in the pig. In the present investigation, the superficial gland is sebaceous in type. The alveolar cells were subdivided into three types: undifferentiated, differentiating and mature cells.

The present result supports the findings of Fahmy ***et al.*** (1971) that the interlobular ducts in the camel are lined by stratified squamous epithelium and they open onto the surface of the conjunctiva .

The deep gland of the third eyelid of the camel possesses a well developed connective tissue capsule. The capsule consists of dense bundles of collagenous fibres with a few reticular and elastic fibres. The septa originate from the capsule and divide the gland into lobules of different shapes and size. Both the capsule and septa are rich in adipose tissue and blood vessels. The outer surface of the capsule is covered by several layers of stratified squamous epithelium. These results are in agreement with those of Fahmy ***et al.*** (1971), Sayed (1988), Ibrahim (1990) and Fateh el Bab ***et al.*** (1991) in the same species.

Fahmy ***et al.*** (1971) described the deep gland of the camel as a compound and lobulated, whereas Fateh el Bab ***et al.*** (1991) described the gland as compound and alveolar. The present study showed that the

deep gland of the third eyelid of the camel is compound tubuloacinar in type. The secretory endpieces of the gland are lined with pyramidal cells. They rest on a layer of myoepithelial cells. These results are identical with those of Fahmy ***et al.*** (1971), Ibrahim (1990) and Fateh el Bab ***et al.*** (1991) in the same species.

Fahmy ***et al.*** (1971), Sayed (1988), Ibrahim (1990), Nagpal ***et al.*** (1991) and Fateh el Bab ***et al.*** (1991) mentioned that the Harderian gland of the camel is a serous gland. The present study confirms the findings of the above-mentioned authors. In other domestic mammals, the Harderian gland is predominantly serous in the horse and cat (Dellmann and Brown, 1981), seromucous in ruminants (Diesem,1975) water buffalo (Abou-Elmaged, 1997) and dog (Bradley, 1948), and mucous in the pig (Banks, 1993) and birds (Rothwell ***et al.***, 1972).

In the present investigation, the interstitial connective tissue of the deep gland possessed large number of plasma cells. These findings confirm the results of Burns and Maxwell (1979) in the turkey, fowl and duck.

Fahmy ***et al***. (1971) concluded that the interlobular ducts in the camel are lined with simple columnar cells while Ibrahim (1990) mentioned that the main ducts are lined with stratified columnar cells. The present investigation confirmed the previous results. Moreover, goblet cells and pigment granules within the superficial layer of the epithelium of the interlobular and main ducts were demonstrated in this study.

The current study demonstrated varying degrees of P.A.S reactivity in the secretory cells of the deep gland of the third eyelid of the camel. The reaction was more obvious in the goblet cells of the interlobular ducts. A positive reaction in the secretory cells and goblet cells of the deep gland of the third eyelid was also reported in the buffalo

(Das, 1979), dog (Martin ***et al.***, 1988), camel (Sayed, 1988; Ibrahim, 1990), and donkey (Ibrahim, 1990).

The present investigation confirms the findings of Fahmy ***et al.*** (1971) and Ibrahim (1990) that large adipocytes are observed either singly or as aggregations between the secretory endpieces of the deep gland of the third eyelid of the camel. Hoffman (1971) and Wooding (1980) are of the opinion that the Harderian gland of mammals secretes its lipid into the conjunctival sac and thereby moistens the cornea.

V.3. Scanning Electron Microscopy

IV.3.A. The Cornea

The present study supports the findings of Hoffmann (1972) Kuwabara (1983), Lavach (1990), Gelatt (1991) and Eighth ***et al.*** (1997) in the fact that the cells of the corneal epithelium of mammals are flat, polygonal, and subdivided into light and dark cells, and firmly attached to each other by relatively straight cell boundaries. The surfaces of the

corneal epithelial cells possess numerous large microvilli and microplicae. Kuwabara (1983) suggested that these microvilli aid in maintaining the moisture of the epithelial cells.

In the present investigation, the endothelium covering the posterior surface of the cornea appeared as a regular mosaic of hexagonal cells. The surface of these cells possessed a few microvilli. Similar findings have already been reported in the dog (Stapleton and Peiffer, 1979), cat (Peiffer ***et al.,*** 1981), ox and horse (Gellatt, 1991). Peiffer ***et al.***, (1981) Kuwabara (1983) are of the opinion that the endothelial cells are essential for maintaining transparency by virtue of a physiological pump mechanism for moving stromal fluid into the aqueous humor.

IV.3.B. The Retina

The ultrastructural appearance of the pigment epithelium of the retina in the present study was generally similar to that of other animals so far studied by Ts'o and Freidman (1967) including the ox, sheep, goat, monkey, rabbit, rat, chicken and man. The retinal pigment epithelium is characterized by a remarkable regularity of the mosaic pattern of the hexagonal cells and particularly by the combination of the various types of pigment granules.

Eighth ***et al.*** (1997) concluded that the photoreceptor cells of the retina, in most domestic mammals, are arranged as a mosaic and are divided into two portions: inner segment and outer segment. The present findings are in agreement with the previous results, and moreover, the outer segment could also be demonstrated as a fingerlike body.

In the present study, the outer limiting membrane, outer nuclear layer and optic nerve fibre layers were demonstrated for the first time by the electron scanning microscopy. The author was un be able to find similar findings in the available literature.

IV.3.C. The Third Eyelid

In the present investigation, the cells of the epithelium of the third eyelid are arranged in a mosaic like pattern of hexagonal cells. They possess numerous microvilli and they are classified into light and dark cells. These results are identical with those of Weyrauch (1984) in the ox, sheep and goat. The present investigation demonstrated the presence of numerous goblet cells within the epithelium as reported by Weyrauch (1984) in the ox, sheep and goat.

IV.4. Transmission Electron Microscopy

IV.4.A. The Choroid and Retina

Similar to that of the ox (Mason ***et al.***, 1973), horse (Wouters and DeMoor, 1979), and dog (Dellmann and Brown, 1981) the basal complex layer of the choroid in the camel, in the present study, possessed high concentration of collagen and elastic fibres with tight junctions between them. Wouters and DeMoor (1979) mentioned that substances are

inhibited to pass across the retinal epithelium through the intercellular clefts of the basal complex layer of the choroid of the horse.

In the present investigation, the endothelium of the choriocapillaris layer of the choroid of the camel, as in the ox (Mason ***et al.***, 1973), horse (Wouters and DeMoor, 1979) and dog (Dellmann and Brown, 1981), is thin and fenestrated. Wouters and DeMoor (1979) elicited that the endothelial wall facilitates diffusion of substances out of the capillaries into the pigment epithelium of the horse.

The pigment epithelium consisted of a single layer of cells with minimal basal infoldings and numerous apical microvilli. These observations are similar to those described in the ox (Mason ***et al.***, 1973), horse (Wouters and DeMoor, 1979), dog (Dellmann and Brown, 1981) sheep, pig, monkey, cat and duck (Braekevelt, 1983a, 1983b, 1987, 1990a, 1990b, 1990c).

Braekevelt (1983a, 1983b, 1987, 1990a, 1990b, 1990c) mentioned that the pigment epithelial cells are attached to each other by tight junctions at the lateral cell borders in sheep, pig, monkey, cat and duck. A similar observation is also noted in the present study. Griff (1990) suggested that these tight junctions form a barrier of considerable electrical resistance

Numerous melanin granules are present in the retinal pigment epithelium of sheep, pig, monkey, cat and duck (Braekevelt, 1983a, 1983b, 1987, 1990a, 1990b, 1990c). Similar findings are found in the present study. However, Nilsson ***et al.*** (1973a) stated that the retinal pigment epithelium of sheep was devoid of melanin granules. It could be suggested that their specimens might be collected from the tapetal area of the fundus, which is known to lack these pigment granules.

The basal aggregations of mitochondria observed in the present study were also noted by Braekevelt (1983a, 1983b, 1987, 1990a, 1990b,

1990c) in sheep, pig, monkey, cat and duck and it is suggested that the basal accumulation of mitochondria might support an active role in the metabolic transport across the pigment epithelium.

The presence of large lipid droplets in the pigment epithelium has been observed in sheep (Nilsson ***et al.***, 1973a). They are also well represented in the present investigation. Young and Bok (1970) suggested that the large lipid droplets of the pigmented epithelium of the frog may be important sites for the storage of vitamin A and related compounds.

The ultrastructural investigation of the photoreceptor cells of the camel revealed that both rods and cones consisted of an outer segment, a connecting cilium and inner segment. Such an observation is also noted by Nilsson ***et al.*** (1973b) in sheep and by Braekevelt (1983a, 1983b, 1987, 1990a, 1990b, 1990c) in sheep, pig, monkey, cat and duck. The large accumulation of mitochondria at the apex of the inner segment observed in the present study is also noted by Nilsson ***et al.*** (1973b) in sheep. Dellmann and Brown (1981) pointed out that the rod cells are responsible for vision in dim light, while the cone cells function in bright light and are responsible for color vision.

The present findings confirmed the results of Nilsson ***et al.*** (1973b) in sheep that the external limiting membrane possessed a series of zonulae adherents between Muller cells and photoreceptor cells.

IV.4.B. The Third Eyelid

The present investigation confirmed the findings of Kuwabara (1983) in that the epithelial cells are arranged into three layers: superficial, intermediate and basal cells.

Like that of mammals (Eighth ***et al.***, 1997), the superficial cells of the epithelial layer of the third eyelid of the camel are joined by junctional complexes.

In the present study, the basal cells of the epithelial layer of the third eyelid contained large and dense nuclei, and they are attached to the basal lamina by desmosomal or hemidesmosomal attachments. These findings are similar to the results of Kuwabara (1983) in some mammals.

The present study is in agreement with that of Eighth ***et al.*** (1997) who reported the presence of numerous goblet cells either individually or in groups associated with epithelial crypts. They are classified into dark and light goblet cells.

IV.4.C. The Superficial Gland

The ultrastructural investigation of the superficial gland of the third eyelid of the camel revealed that the cells were subdivided into: undifferentiated, differentiating and mature cells. Such an observation is also described by Bell (1971) in primates and by Montagna and Parakkal (1974) in sebaceous glands of mammals.

The presence of free ribosomes and tonofilaments has been observed in primates (Bell, 1971) and mammals (Montagna and Parakkal, 1974). They are also well represented in the present study in the undifferentiated cells of the superficial gland of the third eyelid in the camel. Desmosomal attachments are observed between adjacent undifferentiated cells, while hemidesmosomes connect the undifferentiated cells to the basal lamina.

The present investigation confirmed the results of Montagna and Parakkal (1974) that the differentiating cells possess numerous free ribosomes and a variable number of different-sized sebum vesicles. The plasma membranes of differentiating cells possess short folds which interdigitate with each other.

The mature cells of mammalian sebaceous glands were large, deformed cells and contained smooth surfaced-vesicles, some ribosomes, tonofilaments and small mitochondria (Bell, 1971). These results are similar to the present observations.

IV.4.D. The Deep Gland

The present results and the findings of Paule ***et al.*** (1955) in the rat, Bucana and Nadakavukaren (1972) in the hamster, Maxwell and Burns (1979) in the fowl, turkey, duck, Martin ***et al.*** (1988) in the dog, Abou-Elmaged ***et al.*** (1990) in the camel and Abou-Elmaged (1997) in the buffalo agree that the most characteristic features of the secretory cells of the deep gland of the third eyelid of the above mentioned species are the presence of a variable amount of secretory granules accumulating in the apical cytoplasm, Golgi apparatus located in the supranuclear area, rough endoplasmic reticulum and oval nuclei occuping the basal cytoplasm. The apical surface of the secretory cells is covered by microvilli projecting into the lumen of the secretory endpieces.

Sayed (1988) and Abou-Elmaged ***et al.*** (1990) reported that the secretory cells of the camel deep gland showed ultrastructural characteristics of typical merocrine secretory activity. On the light of the present ultrastructural results, the secretory cells of the camel deep gland of the third eyelid may have similar activities.

Many large goblet cells were observed throughout the epithelial lining of the duct of the turkey, fowl, duck (Maxwell and Burns, 1979), dog (Martin ***et al.***, 1988), camel (Sayed, 1988; Abou-Elmaged ***et al.***, 1990) and buffalo (Abou-Elmaged, 1997). In the present investigation, the goblet cells possess both light and dark mucous granules and a few microvilli at their luminal surface.

The number of the goblet cells reported in this study, and the copious of mucus in the content ductal secretory vesicles, indicate that the

ducts of the deep gland produce much mucoid secretion. Since it is known that the Harderian gland is involved in immunity (Mueller, Sato and Glick, 1971) it may be speculated that this secretion may have some immunological significance.

Similar to that of the turkey, fowl, duck (Maxwell and Burns, 1979), dog (Martin ***et al.***, 1988), camel (Sayed, 1988; Abou-Elmaged ***et al.***, 1990) and buffalo (Abou-Elmaged, 1997), the myoepithelial cells of the deep gland of the camel, in the present investigation, were well represented either around the glandular end-pieces or around the intralobular ducts. Abou-Elmaged (1997) subdivided the myoepithelial cells of the buffalo Harderian gland into a cell body and cytoplasmic processes. Hoffman (1971) and Wooding (1980) pointed out that the myoepithelial cells are contractile elements, facilitating extrusion of the scretory products.

Sayed (1988) and Abou-Elmaged ***et al.*** (1990) mentioned the presence of lipid droplets in the cells of the deep gland of the camel. A similar observation is also noted in the present study. Martin ***et al.*** (1988) suggested that these lipid droplets are unique in being elaborated by merocrine secretion.

Abou-Elmaged (1992) reported that the course of the intercellular nerve terminals of the camel consist of mitochondria, a few number of electron dense granules and many small clear vesicles. A similar observation is also noted in the present investigation.

IV.5. Morphometry

The available literature reveals that there is no information pertaining to morphometric study of the superficial and deep gland of the third eyelid of any of the domestic mammals.

With reference to the available literature, no morphometric study was conducted on the superficial and deep gland of the third eyelid of the dromedary camel.

In the present investigation, the morphometric analysis of the superficial gland of the third eyelid revealed that the volume densities of the glandular tissue, connective tissue, hair follicles and ducts are similar for the right and left glands. Moreover, there is no significant difference between the right and left glands in the relative volumes occupied by these components.

In the camel, Fateh el Bab ***et al.*** (1991) gave an estimation of the endpieces of the deep gland. They reported that the first type is made up of light cells which constitute about 78%, the second type of both light and dark cells constitute about 15% and the third type of dark cells constitute only about 7%.

In the current study, the morphometric analysis of the deep gland of the third eyelid revealed that there is no significant difference between the right and left glands in the relative volumes occupied by the components.

The glandular tissue represents the greater component of the deep gland both in the right gland (65.18%, 1.58 $cm.^3 \pm 0.14$) and in the left gland (67.46%, 1.64 $cm.^3 \pm 0.12$). It worth mentioning that the large amount of the glandular tissue is an indicator to volume of the secretion produced by the cells of the endpieces. The major function of the secretion of the deep gland is attributed to washing and moistening of the anterior part of the eyeball. Therefore, this important function seems to be more suitable for the sandy land and dry environment of the camels habitat.

On the other hand, the connective tissue constitutes about 24.45%, 0.59 $cm.^3 \pm$ 0.03 of the volume of the right gland and 22.30%, 0.50 $cm.^3 \pm$ 0.04 of the volume of the left gland.

CONCLUSIONS

1. The results indicated that most of the histology and ultrastructure of the eyeball are similar to those of other domestic mammals.
2. The macroscopical and histological results indicated that the glands associated with the third eyelid classified into superficial and deep glands. The deep gland (Harderian gland) is supported by many plates of hyaline cartilage.
3. The superficial gland of the third eyelid is found only in the pig and the camel.
4. There were numerous lymph nodules in the conjunctiva which covers the eyelids, third eyelid and the glands of the third eyelid.
5. Morphometric data on glands of the third eyelid were provided for the first time.
6. The morphometric results revealed that there was no significant difference between the right and left superficial gland and of the right and left deep gland of the third eyelid of the camel.
7. The glandular tissue constituted the largest components of the superficial glands volume (65.20% in right side and 63.83% in left side) and deep glands volume (65.18% in the right side and 67.46% in the left side).
8. Future work will be concentrated on the blood supply and venous drainage of the eyeball and its appendages. The muscles of the eyeball and their innervation will also be investigated. Optic disc, macula and limbus will also be investigated by scanning and transmission electron microscopy.

SUMMARY

1. Gross anatomical and histological study has been conducted on the eyeball and its appendages on forty three camels (*Camelus dromedarius*) of both sexes and of different ages.
2. Scanning electron microscopy of the cornea, retina and third eyelid was investigated in three camels.
3. Transmission electron microscopy of the retina, third eyelid , superficial and deep gland of the third eyelids was studied in three camels.
4. The morphometry of the superficial and deep glands of the third eyelid was studied in three camels.
5. The eyeballs were directed towards the lateral side of the orbit and they were enclosed in a considerable amount of adipose tissue.
6. The most significant feature of the camel eyeball layers is the existence of melanocytes in the sclera, corneoscleral junction, iris and ciliary body.
7. The tapetum lucidum of the choroid is absent in the camel. This could be attributed to the environment in which the camels normally live, where adequate light is available.
8. The dromedary camel has superficial and deep glands of the third eyelid.
9. These glands are surrounded by a capsule which is covered by stratified squamous epithelium with large goblet cells.
10. The superficial gland of the eyelid is tubulo-alveolar, and the alveolar cells are classified into three types: undifferentiated, differentiating and mature cells. One or two alveoli are associated with each hair follicle.

11. The deep gland of the third eyelid is tubuloacinar, and the scretory endpieces are lined with a single layer of pyramidal cells and the interstitial connective tissue contains lymphocytes, plasma cells, fibroblast and blood vessels.
12. The interlobular and main ducts are lined with stratified squamous epithelium rich in melanin granules and goblet cells.
13. The presence of several plates of hyaline cartilage within the parenchyma of the deep gland is a prominent feature.
14. The histological and ultrastructure studies of the retina revealed it is typically made up of 10 layers.
15. The ultrastructure demonstrated the presence of melanin granules and lipid droplet in the cytoplasm of the retinal pigment epithelial cells, and large goblet cells within the epithelial cells of the third eyelid. These goblet cells contain either light or dark granules.
16. There is no significant difference between the morphometric results of the right and left superficial glands and the right and left deep glands of the third eyelid.
17. The mean absolute volume of the of the superficial gland of the third eyelid of the right side is about 1.8 c.m.^{3}, whereas that of the left side is about 1.56 cm.^{3}.
18. The glandular tissue constituted the largest component of the superficial gland volume (65.20% in right side and 63.83% in left side).
19. The mean absolute volume of the right deep gland of the third eyelid is about 2.43 cm.^{3} . ± 0.21 (SD), whereas that of the left gland is 2.43 cm.^{3} ± 0.23 (SD).
20. The glandular tissue of the right deep gland of the third eyelid amounts to about 65.18% of the total volume of the gland and that

of the left deep gland amounts to about 67.46% of the total volume of the gland.

الملخص

1- أجريت هذه الدراسة للتعرف علي السمات التشريحية و النسيجية للمقلة وملحقاتها في ثلاث وأربعين من الإبل من الجنسين بمختلف الأعمار.

2- تم الفحص بالمجهر الالكتروني الماسح لكل من القرنية، الشبكية والجفن الثالث في ثلاثة من الإبل.

3- تم الفحص بالمجهر الالكتروني الاختراقى لكل من الشبكية، الجفن الثالث ،الغدة السطحية و الغدة العميقة للجفن الثالث.

4-) تم دراسة القياس الشكلي (المورفومتري) لغدتي الجفن الثالث السطحية والعميقة في ثلاثة من الإبل .

5- تتجة العين الى الناحية الوحشية ، و تحيط بها كمية كبيرة من النسيج الدهنى.

6- توجد الخلايا الصبغية بكثافة في الصلبة، الحوف، القزحية والجسم الهدبي.

7- البساط النير غير موجود في الإبل و ربما يفسر هذا عدم احتياج الإبل لانعكاس الضوء مرة أخري علي الشبكية لكونها موجودة في بيئة ضوئية مناسبة.

8- أظهرت الدراسة وجود نوعين من الغدد مختصة بالجفن الثالث للإبل :غدة سطحية وغدة عميقة. وأيضا أوضحت الدراسة وجود عدة صفات تشريحية ونسيجية مميزة لهذه الغدد.

9- تحاط غدتا الجفن الثالث السطحية والعميقة بمحفظة و هذه المحفظة مغطاة بنسيج طلائي حرشفي مصفف به عدد من الخلايا الكاسية.

10- الغدة السطحية للجفن الثالث عبارة عن غدة نبيبية سنخية و خلاياها مقسمة إلى ثلاثة أنواع: خلايا غير متمايزة ، متمايزة وناضجة.

11- أوضحت الدراسة وجود جريب شعر واحد مع حويصلة أو حويصلتين من حويصلات الغدة السطحيه.

12- الغدة العميقة للجفن الثالث عبارة عن غدة عنيبية و نهاياتها الافرزاية مبطنة بطبقة من الخلايا الهرمية. و تحتوى الغدة على العديد من الخلايا اللمفية و البلزميه و اورمات الألياف و الأوعية الدموية.

13- القنوات بين الفصيصيات والقنوات الإخراجية مبطنة بنسيج حرشفى مصفف بة خلايا كأسية و حبيبات الميلانين.

14- أوضحت الدراسة وجود العديد من صفائح الغضروف الزجاجى فى داخل الغدة العميقة للجفن الثالث.

15- تمت دراسة الشبكية باستخدام المجهر الاختراقى الالكتروني وأظهرت الدراسة وجود العديد من حبيبات الملانين وقطيرات الدهن داخل خلايا النسيج الشبكي الصبغي، وخلايا كأسية كبيرة بين خلايا النسيج ألطلائي المبطن للجفن الثالث. هذه الخلايا الكاسية تحتوي إما علي حبيبات باهتة أو داكنة اللون.

16- لا يوجد فرق واضح في النتائج القياسية الشكلية (المورفومترية) بين الغدتين السطحيتين اليمنى اليسرى للجفن الثالث و الغدتين العميقتين اليمنى اليسرى للجفن الثالث.

17- متوسط الحجم للغدة السطحية اليمنى هو $1.8\ cm^3$ بينما متوسط الحجم في الغدة السطحية اليسرى $1.56\ cm^3$.

18- وجد أن النسيج الغدي للغدة السطحية هو المكون الأكبر من حجم الغدة في كلا الجانبين (65.20% في الجانب الأيمن و 63.83% في الجانب الأيسر) .

19- متوسط الحجم للغدة العميقة اليمني للجفن الثالث حوالي $2.43\ cm^3 \pm 0.21$ (SD) بينما متوسط الحجم للغدة العميقة اليسرى $2.43\ cm^3 \pm 0.23$ (SD)

20- النسيج الغدي في الغدة العميقة اليمني بشكل تقريبا 65.18% من حجم الغدة الكلي بينما يشكل النسيج الغدي في الغدة العميقة اليسرى 67.46% من حجم الغدة الكلي.

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FIGURES

Figure 1: A photograph showing the topography of the **right eyeball** and its appendages.

1. The medial canthus
2. The lateral canthus

Note the triangular hairy area at the medial side of the upper eyelid (arrows).

Figure 2: A photograph to indicate the locations of the **third eyelid and the superficial gland.**

1. The third eyelid.
2. The superficial gland.
3. The adipose tissue.
4. The lateral canthus.

1

2

Figure 3: A photograph showing the appearance of the **eyeball** outside the orbit.

1. The cornea.
2. The sclera.
3. The optic nerve.

Figure 4: A photograph showing the shape of the **deep gland of the third eyelid.**

Note the presence of pigmented streaks on the surface of the gland (arrows).

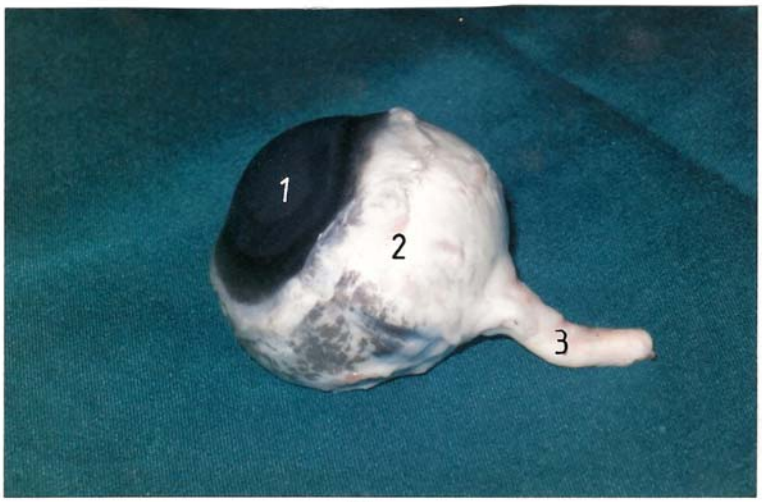

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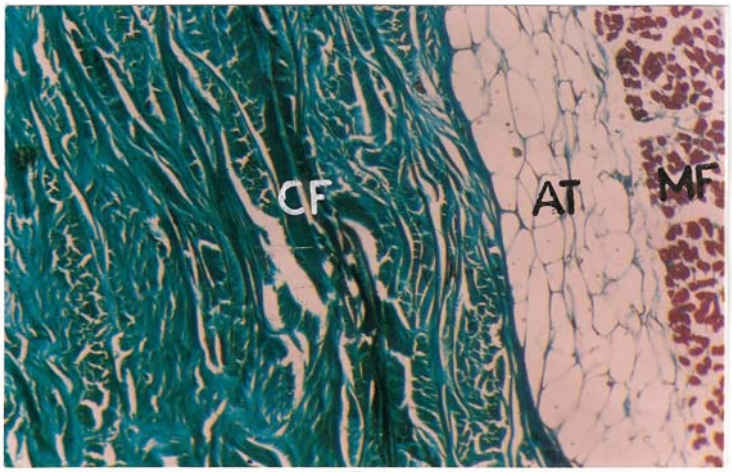
Figure 5: A photomicrograph of the **sclera** showing bundles of collagen fibres (CF), adipose tissue (AT) and bundles of muscle fibres (MF).

Masson's trichrome stain. X100.

Figure 6: A photomicrograph of the **cornea** showing the corneal epithelium (CE) resting on a thin basement membrane (arrows) and the corneal stroma (CS).

H & E stain. X 500.



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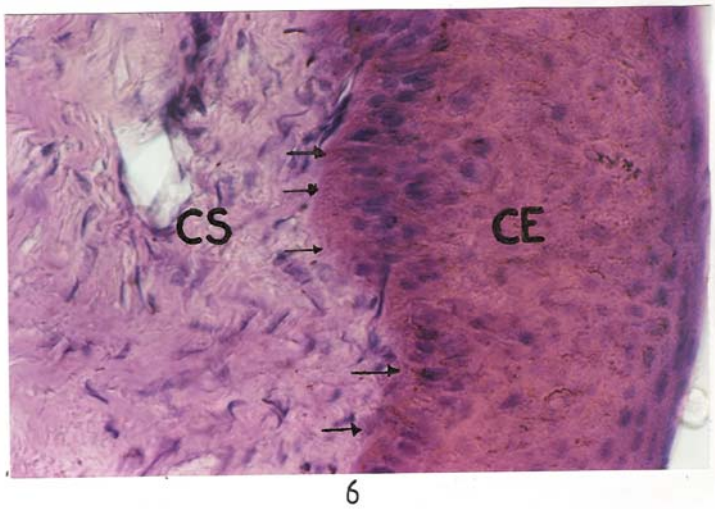

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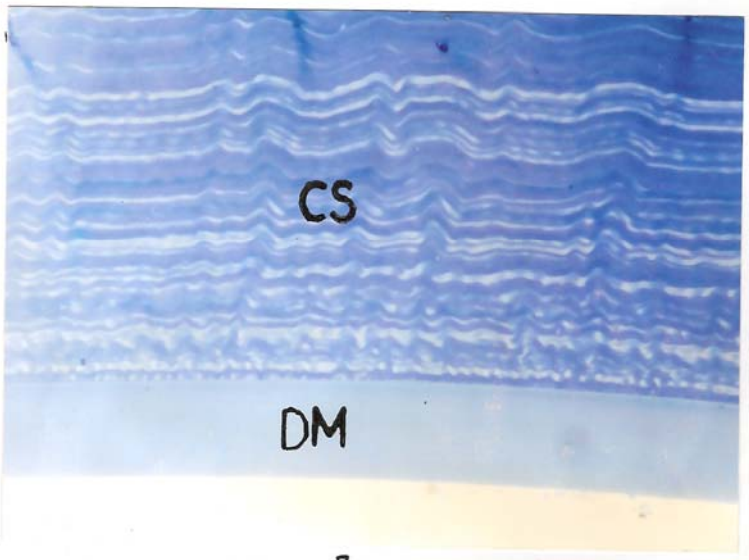
Figure 7: A photomicrograph of the **cornea**. The corneal stroma (CS) rests on Descemet's membrane (DM).
Toluidine blue stain. X 250.

Figure 8: A photomicrograph of **the cornea**. The corneal stroma (CS) at the limbus. Note the pigment granules (arrows).
Masson's trichrome stain. X100.



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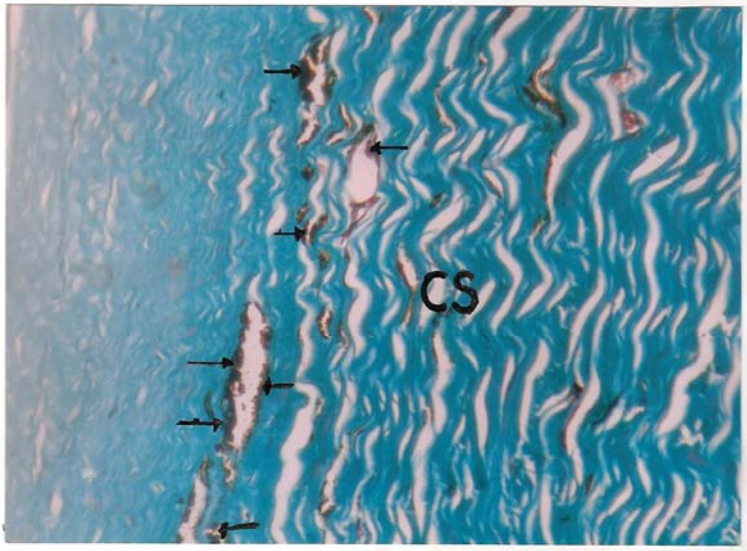

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Figure 9: A photomicrograph of the **choroid** showing the suprachoroid layer (SC), vessel layer (V), branched pigmented cell (P) and retinal pigmented epithelium (arrows).

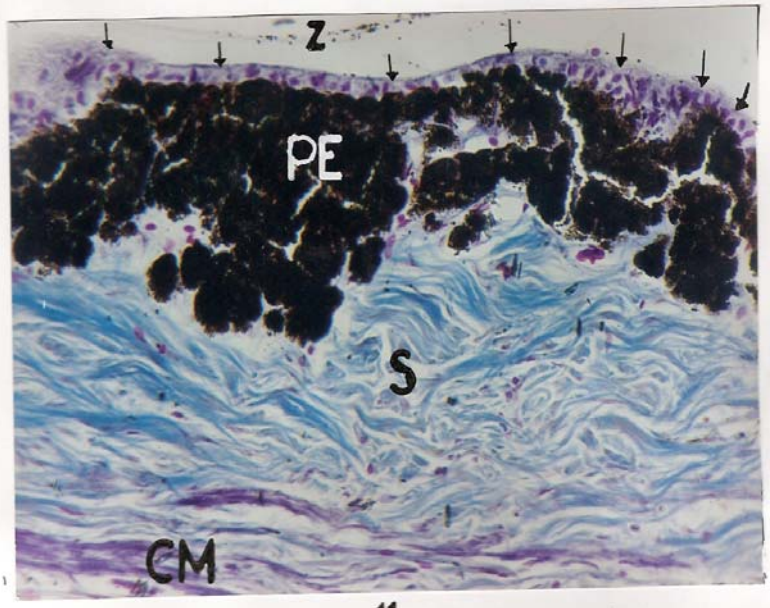
Masson's trichrome stain. X500.

Figure 10: A photomicrograph of the **choroid** showing the suprachoroid layer (SC), vessel layer (V), choriocapillary layer (arrows) Bruch's membrane (arrowheads), and retinal pigmented epithelium (RP). Note melanocytes (M) in the stroma.

Toluidine blue stain. X1000.

Figure 11: A photomicrograph of the **ciliary body**. The ciliary epithelium consists of non pigmented (arrows), pigmented epithelium (PE), stroma (S) and ciliary muscle (CM). **Masson's trichrome stain. X 250.**

Figure 12: A photomicrograph of the **ciliary body** showing the ciliary processes (arrows) of the ciliary body (CB). Note the iris (I) iridocorneal angle (IC) and the cornea (C).
H & E stain. X 40.



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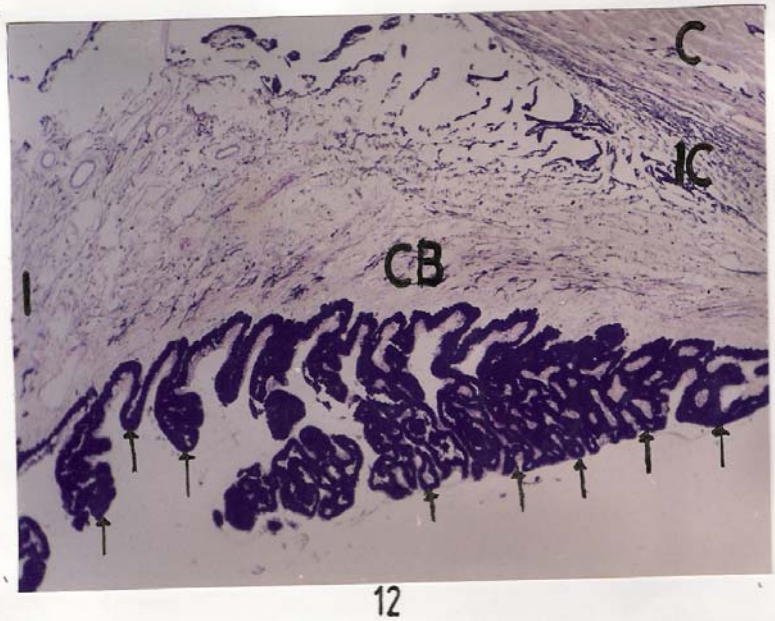

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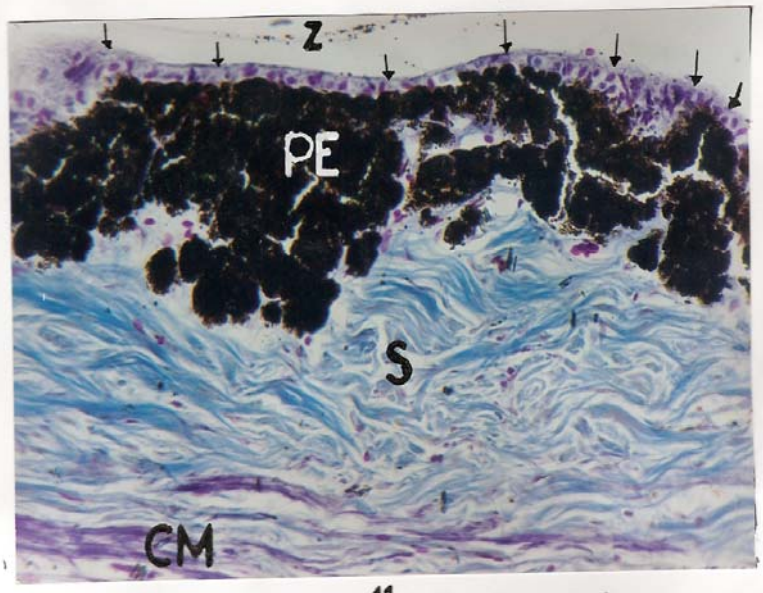
Figure 13: A photomicrograph of the **ciliary body**. The ciliary processes showing the ciliary epithelium consisted of an inner non-pigmented (NP), an outer pigmented layers (PE) and blood vessels (V).

Masson's trichrome stain. X 500.

Figure 14: A photomicrograph of the **iris**. The anterior surface (A) consists of thin epithelial layer (TE) supported by iris stroma (IS). The iris stroma consists of thin bundles of collagen fibres (CF) and branched pigment cell (P).

H & E stain. X 250.



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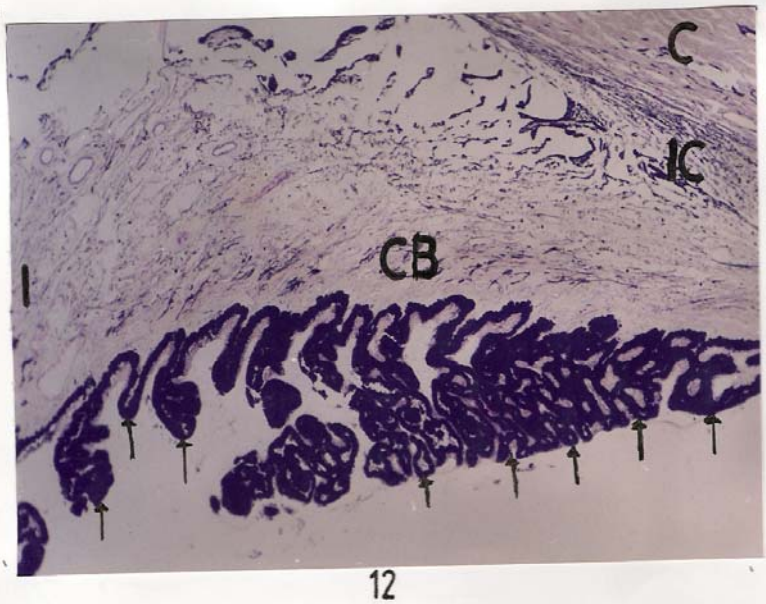

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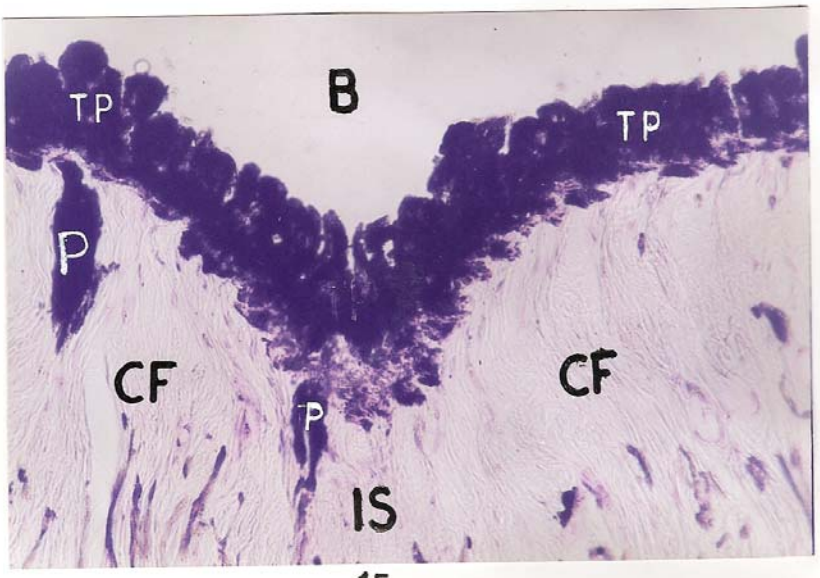
Figure 15: A photomicrograph of the **iris**. The posterior surface (B) is formed by thick pigmented epithelial layer (TP) and supported by iris stroma (IS). The iris stroma consists of thin bundles of collagen fibres (CF) and branched pigment cell (P).

H & E stain. X 250.

Figure 16: A photomicrograph of the **iris** showing the sphincter pupillary muscle (C) and branched pigmented (P) cells in the iris stroma (IS) .

H & E stain. X 250.



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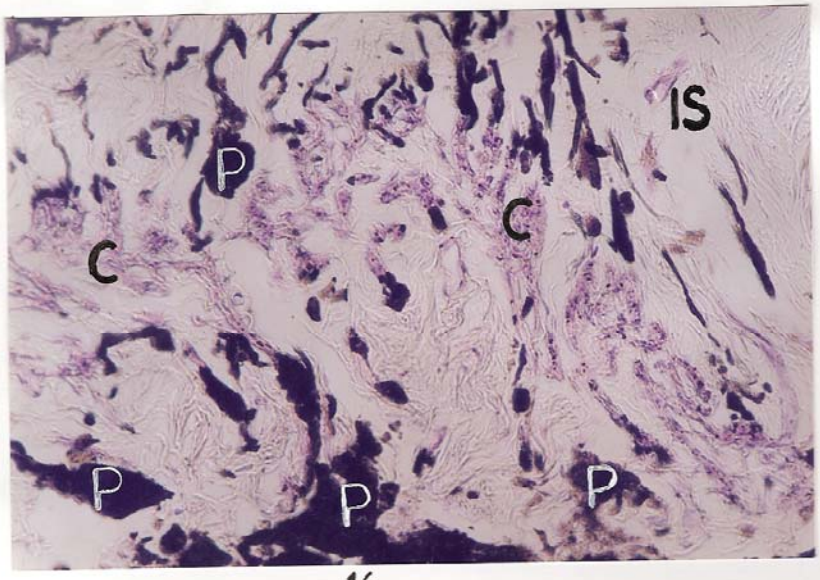

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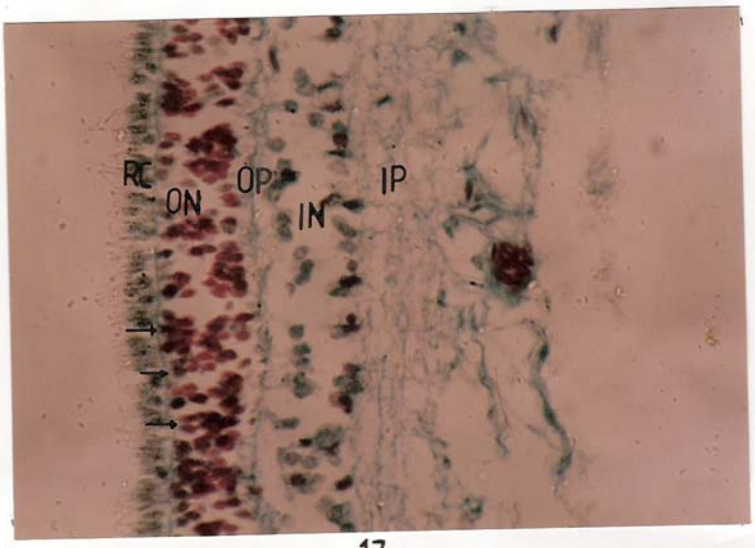
Figure 17: A photomicrograph of the **retina** demonstrating the rods and cones layer (RC), outer limiting membrane (arrows), outer nuclear layer (ON), outer plexiform layer (OP), inner nuclear layer (IN) and inner plexiform layer (IP).

Masson's trichrome stain. X 1000.

Figure 18: A photomicrograph of the **eyelid**. The outer surface (OS) is covered by keratinized stratified squamous epithelium (K) resting on stroma (S).

H & E stain. X 100.



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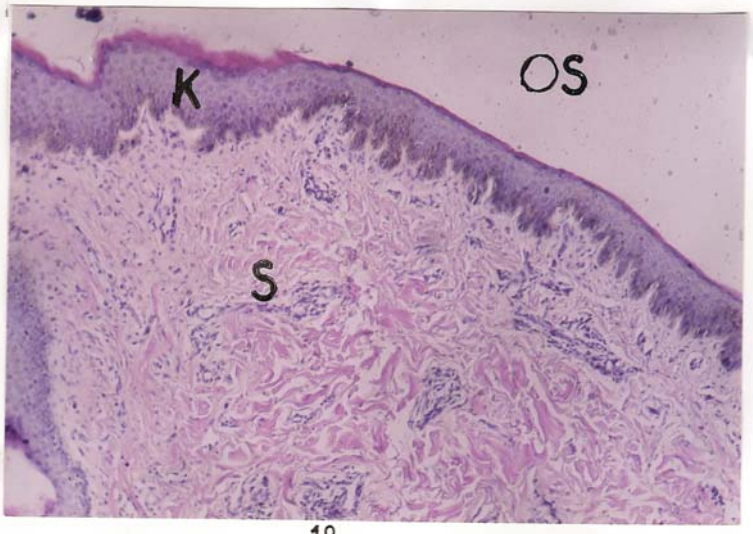

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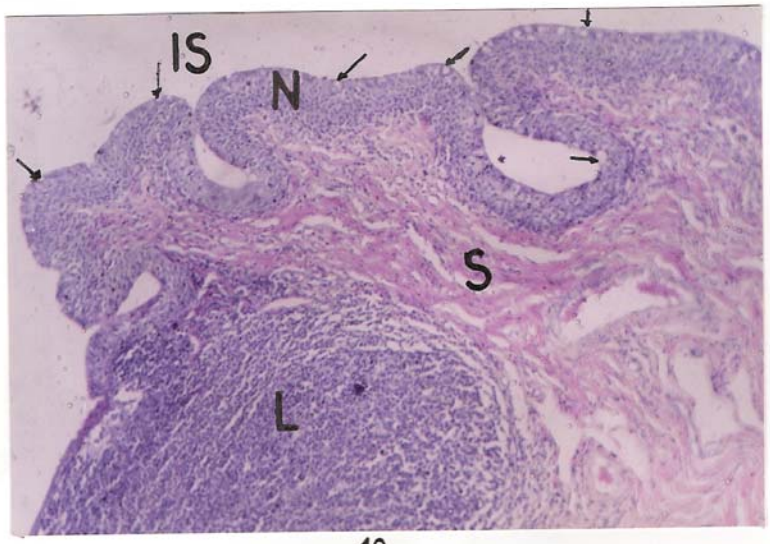
Figure 19: A photomicrograph of the **eyelid**. The inner surface (IS) is covered by nonkeratinized squamous epithelium (N) with large goblet cells (arrows). Note the lymphatic nodule (L) within the stroma (S).

H & E stain. X 100.

Figure 20: A photomicrograph of the **eyelid**. The inner surface showing numerous goblet cells (arrows) and supported by connective tissue (C).

PAS stain. X 100.



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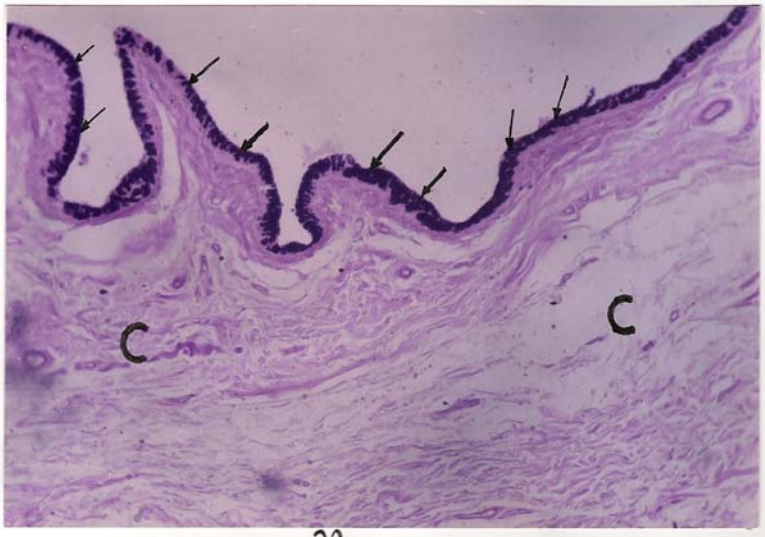

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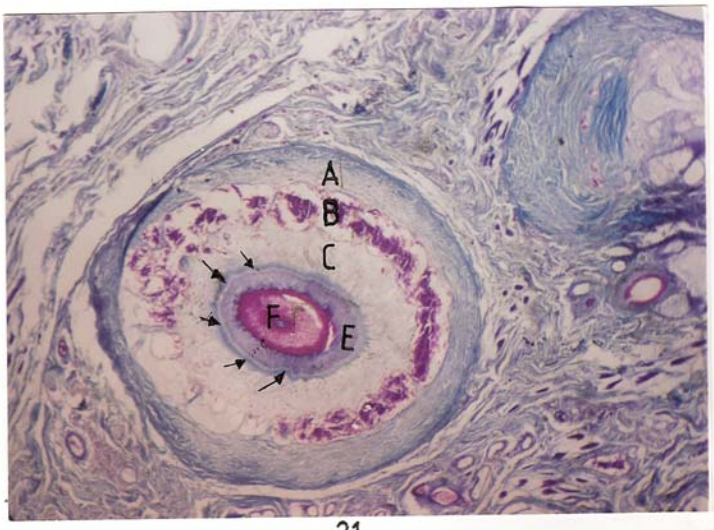
Figure 21: A photomicrograph of the **eyelid**. Cross section of sinus hair follicle showing the outer layer of dermal sheath (A), blood sinus with trabeculae (B), inner layer of dermal sheath (C), glassy membrane (arrows), external root sheath (E) and hair root (F).

Masson's trichrome stain. X 40.

Figure 22: A photomicrograph of the **eyelid**. Cross section of sinus hair showing the outer layer of dermal sheath (A), blood sinus with trabeculae (B), inner layer of dermal sheath (C), glassy membrane (arrows), external root sheath (E), hair (F) and nerve fibres (N).

Masson's trichrome stain. X 40.



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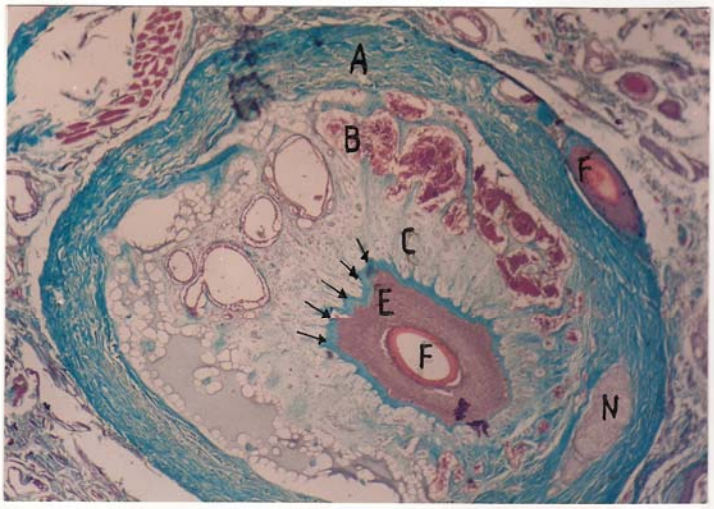
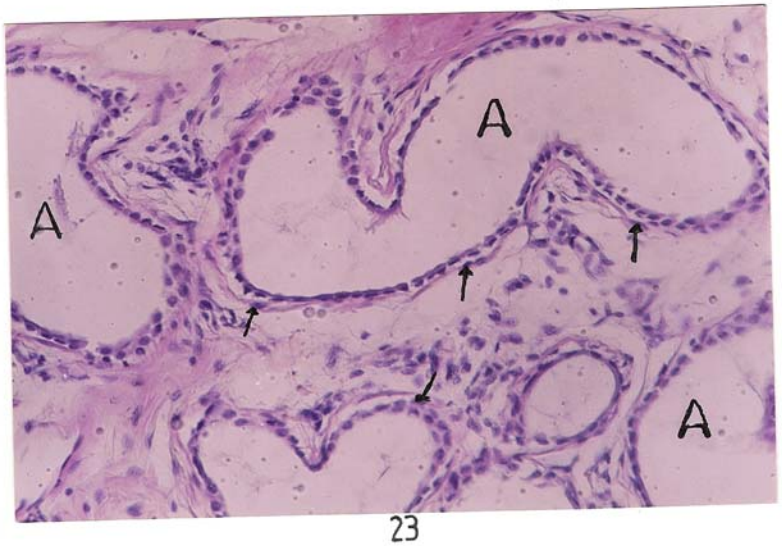


22

Figure 23: A photomicrograph of the **eyelid**. A sweat gland showing secretory portions (A) and myoepithelial cells (arrows)
H & E stain. X 250.

Figure 24: A photomicrograph of the **eyelid** showing few reticular fibres in the subepithelial layer and around sebaceous gland (arrows).
Gomori's silver stain. X500.



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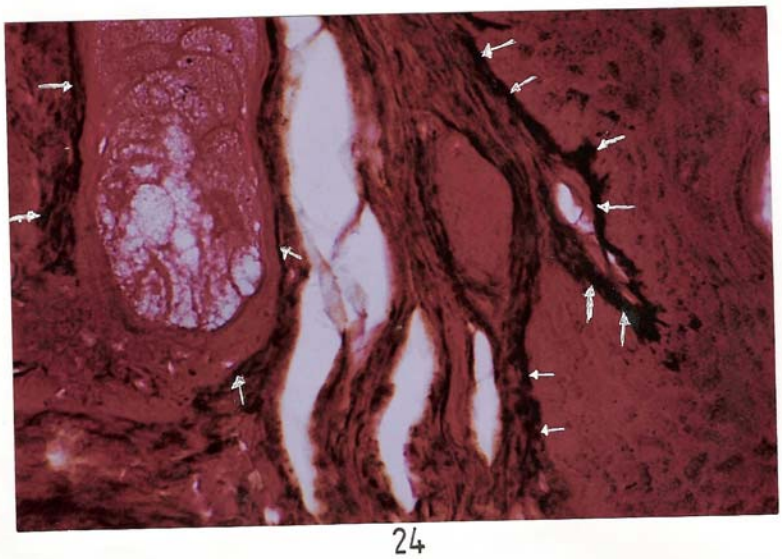

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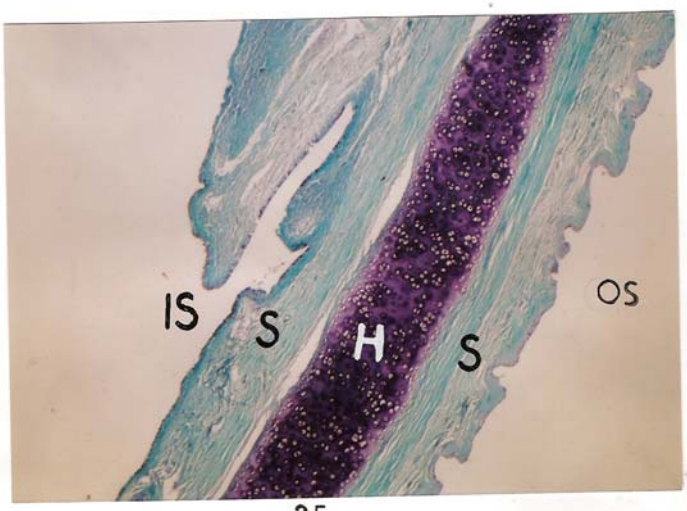
Figure 25: A photomicrograph of the **third eyelid** showing the outer surface (OS), the stroma (S), hyaline cartilage (H) and inner surface (IS).

Aldehyde fuchsin stain. X100.

Figure 26: A photomicrograph of the **third eyelid** showing the outer surface (OS), stroma (S), hyaline cartilage (H), inner surface (IS) and goblet cells (arrows).

PAS stain. X 40.



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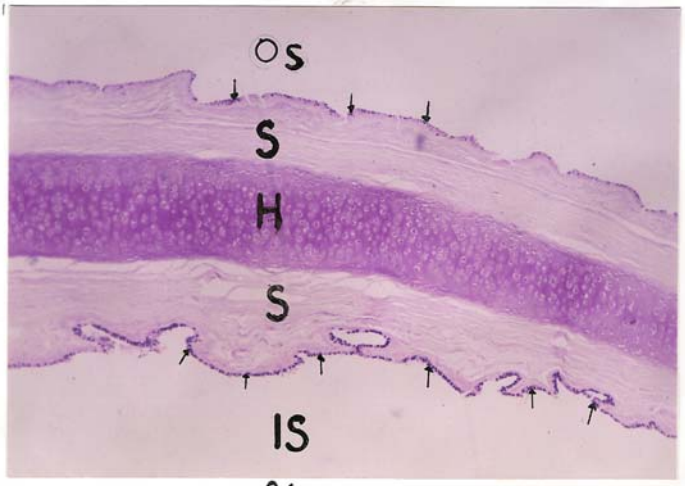

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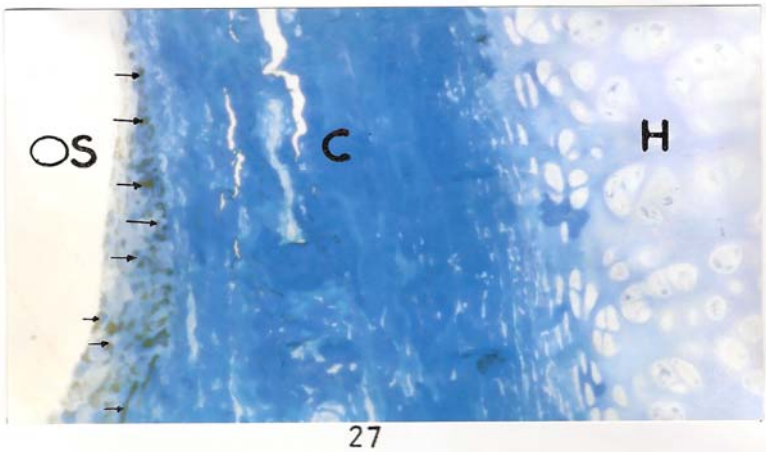
Figure 27: A photomicrograph of the **third eyelid**. The outer surface (OS) possesses pigment cells (arrows). Large bundles of collagen fibres (C) surround hyaline cartilage (H).

Toluidine blue stain. X250.

Figure 28: A photomicrograph of the **third eyelid**. The outer surface (OS) possesses numerous goblet cells (arrows).

Toluidine blue stain. X1000.



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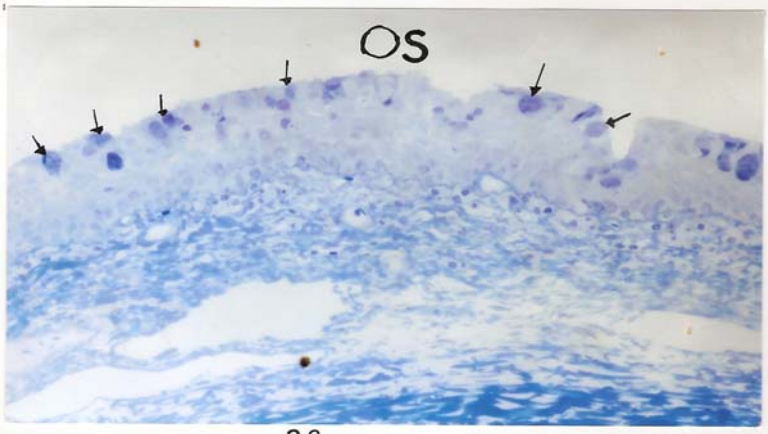

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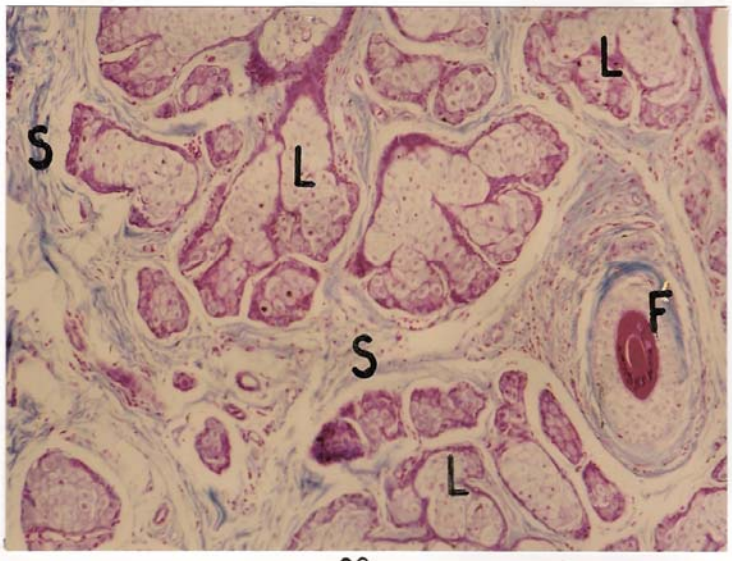
Figure 29: A photomicrograph of the **superficial gland of the third eyelid** demonstrating the lobules (L) of the gland separated by thin septa (S). Note the hair follicle (F) within the parenchyma of the gland.

Masson's trichrome stain. X 1000.

Figure 30: A photomicrograph of the **superficial gland of the third eyelid** showing the lobule (L) surround by thick septa (S). Note the hair follicle (F) within the cells of lobule.

Masson's trichrome stain. X 1000.



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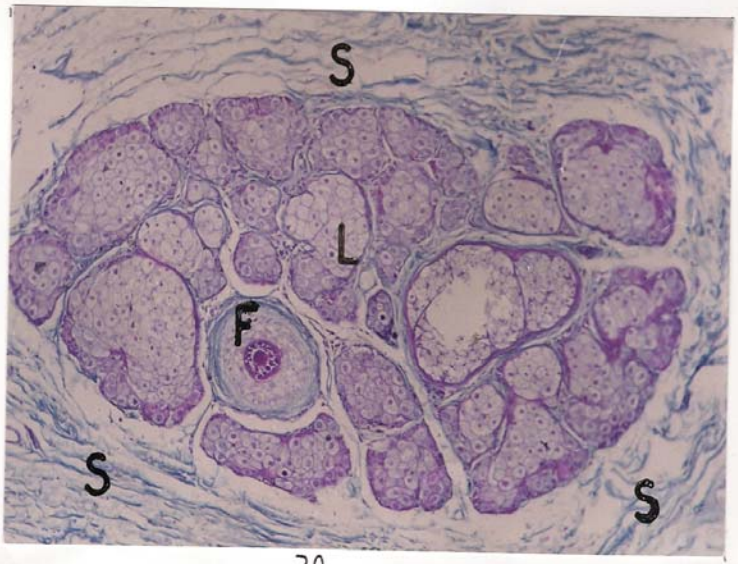

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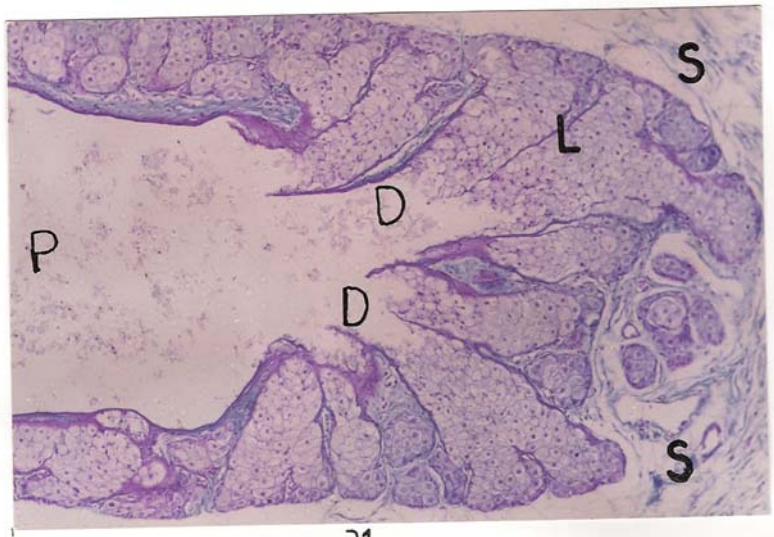
Figure 31: A photomicrograph of the **superficial gland of the third eyelid** showing the lobule (L) surround by septa (S), duct (D) and pilosebaeous canal (P).

Masson's trichrome stains. X 100.

Figure 32: A photomicrograph of the **superficial gland of the third eyelid** showing the stratified squamous epithelium (A) covering the capsule (C), thick trabeculae (T1), thin trabeculae (T2) and lobule (L).

Toluidine blue stain. X 250.



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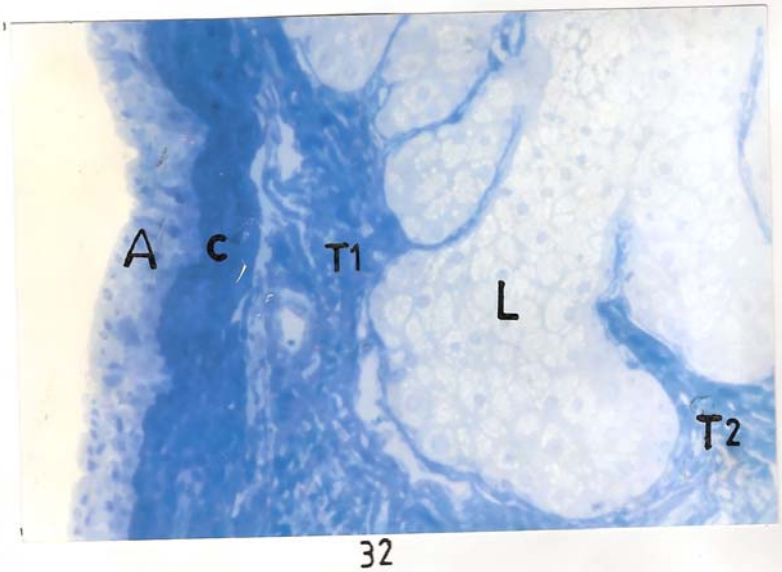

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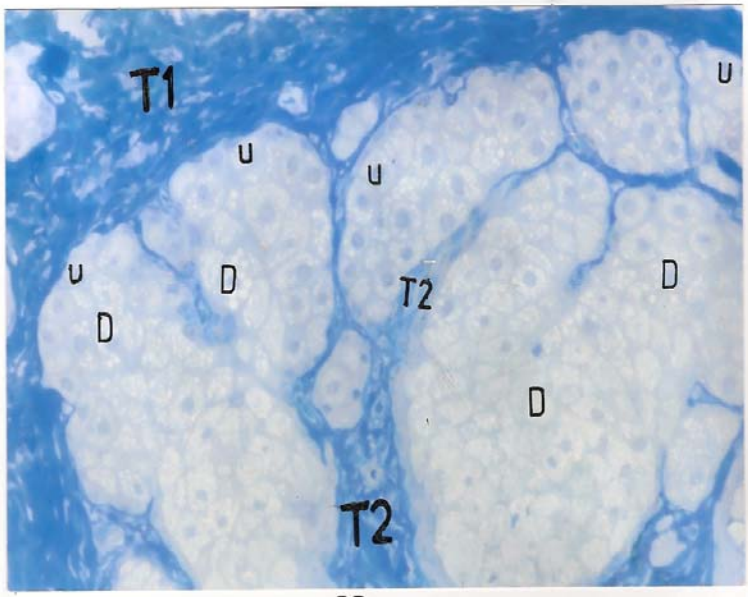
Figure 33: A photomicrograph of the **superficial gland of the third eyelid** showing thick trabeculae (TI), thin trabeculae (T2), undifferentiated (U) and differentiating cells (D).

Toluidine blue stain. X 250.

Figure 34: Higher magnification of figure 33 showing the nuclei of the differentiating cells (N), fat droplets (F) and myoepithelial cells (M) in the thin trabeculum (T).

Toluidine blue stain. X 1000.



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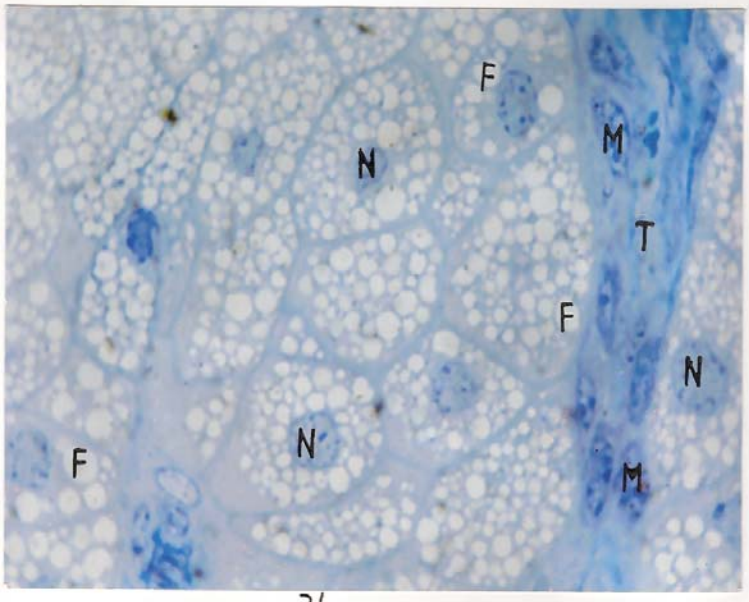

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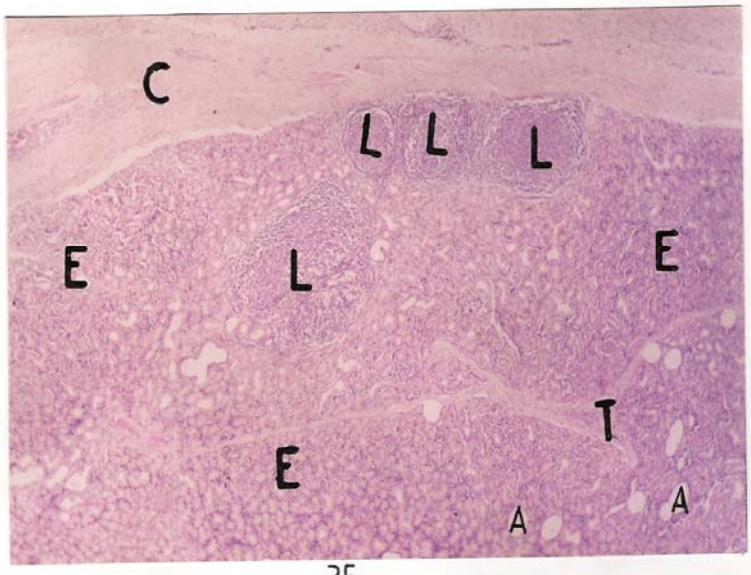
Figure 35: A photomicrograph of the **deep gland of the third eyelid** demonstrating the capsule (C), trabeculae (T), endpieces of gland (E), lymphatic nodules (L) and fat vacuoles (A).

H&E stain. X 40.

Figure 36: A photomicrograph of the **deep gland of the third eyelid**. Elastic fibres of the capsule (C) are shown as wavy longitudinal fibres (arrows). D: ducts, S: secretory units.

Orcein's stain. X 250



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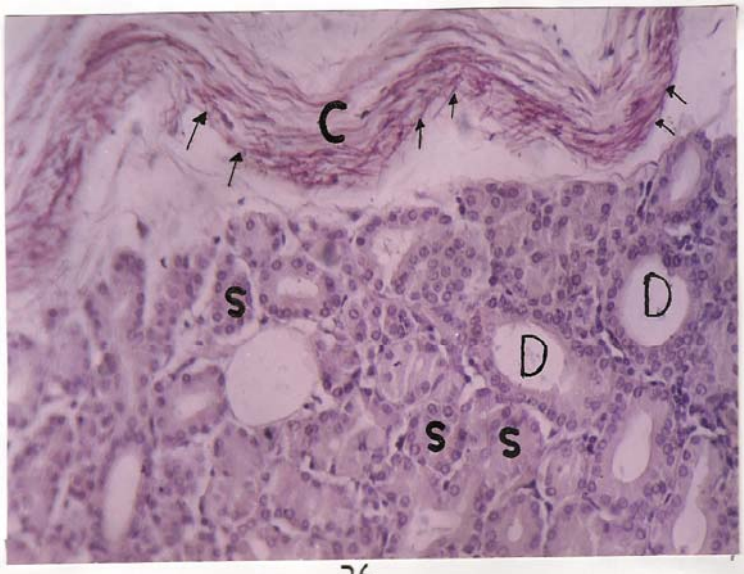
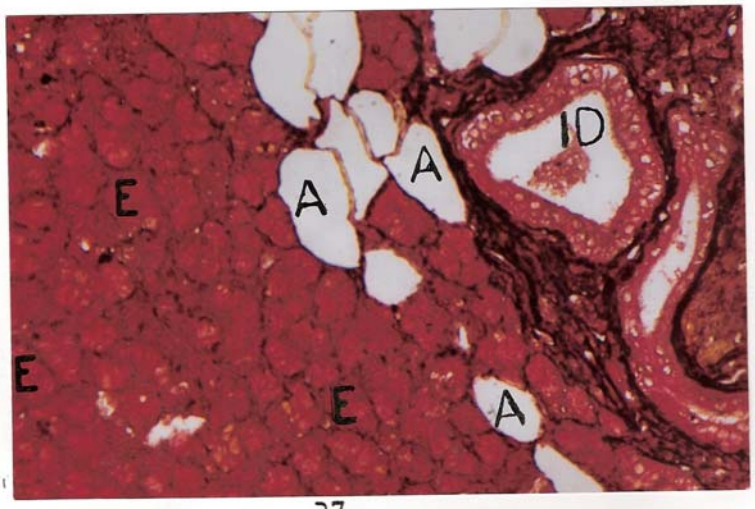


36

Figure 37: A photomicrograph of the **deep gland of the third eyelid** showing reticular fibres around interlobular duct (ID) and around endpieces of the gland (E). Adipocyte (A) are also seen. **Gomori's silver stain. X500.**

Figure 38: A photomicrograph of **the deep gland third eyelid** showing a plate of hyaline cartilage (H) of the gland**.** **Orcein's stain. X 250.**



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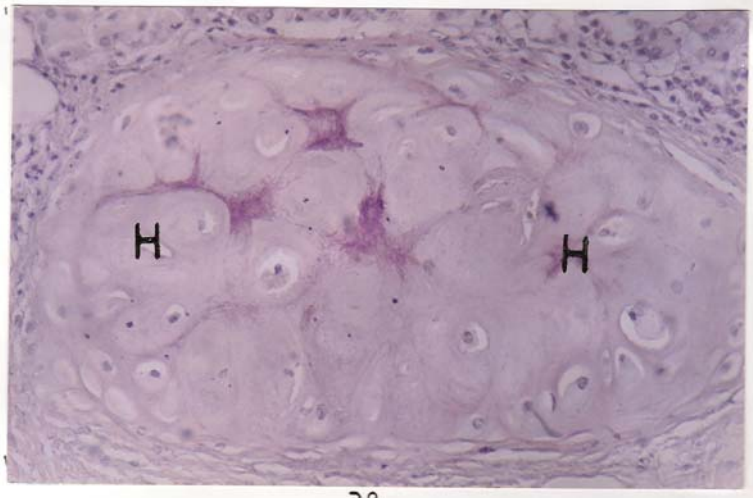

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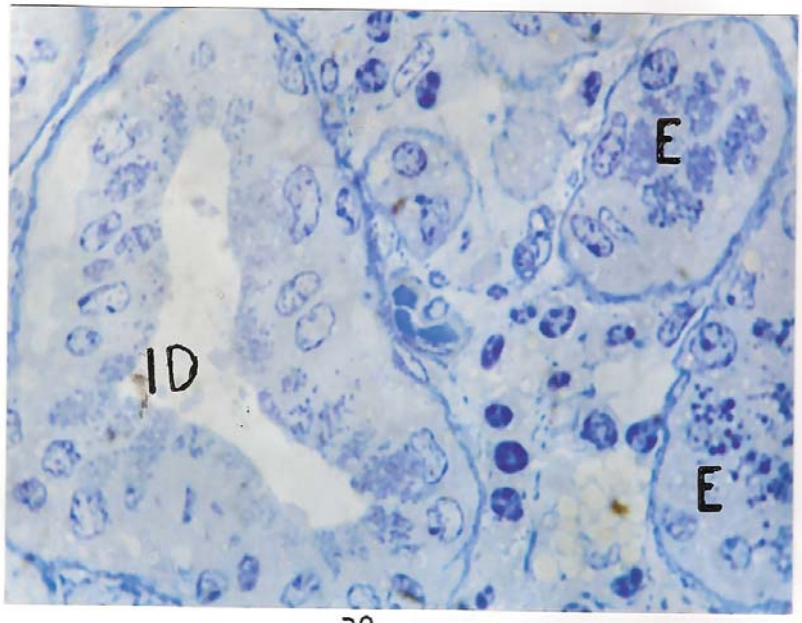
Figure 39: A photomicrograph of the **deep gland of the third of the eyelid**. The interlobular duct (ID) and endpieces (E) are shown. **Toluidine blue stain. X 1000**

Figure 40: A photomicrograph of **the deep gland third eyelid** showing several pigment cells (arrows) within the epithelium of the wall of the main duct, large adipocytes (A) within parenchyma of the gland (E) and septa (S).

Toluidine blue stain. X1000



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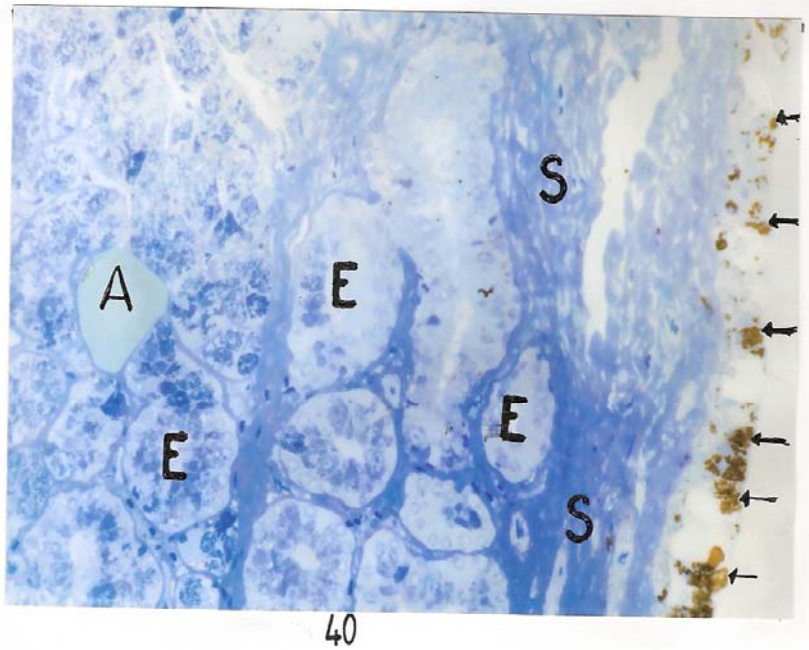

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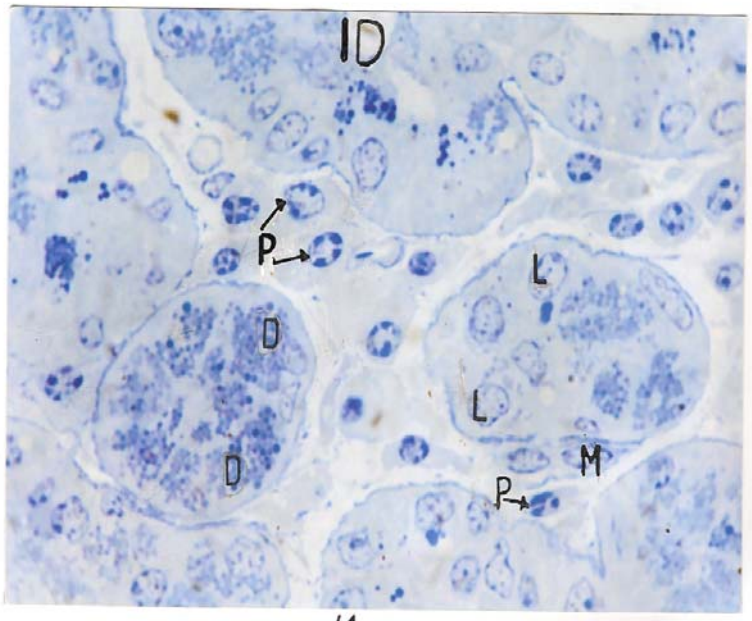
Figure 41: A photomicrograph of the **deep gland of the third eyelid** demonstrating the interlobular duct (ID), dark cell (D), light cell (L) and myoepithelial cell (M). Note the presence of many plasma cells (P) with the interstitial tissue of the gland.

Toluidine blue stain. X 1000.

Figure 42: A photomicrograph of **the deep gland third eyelid** showing the light endpieces (L) and dark endpieces (D).

Toluidine blue stain. X 250.



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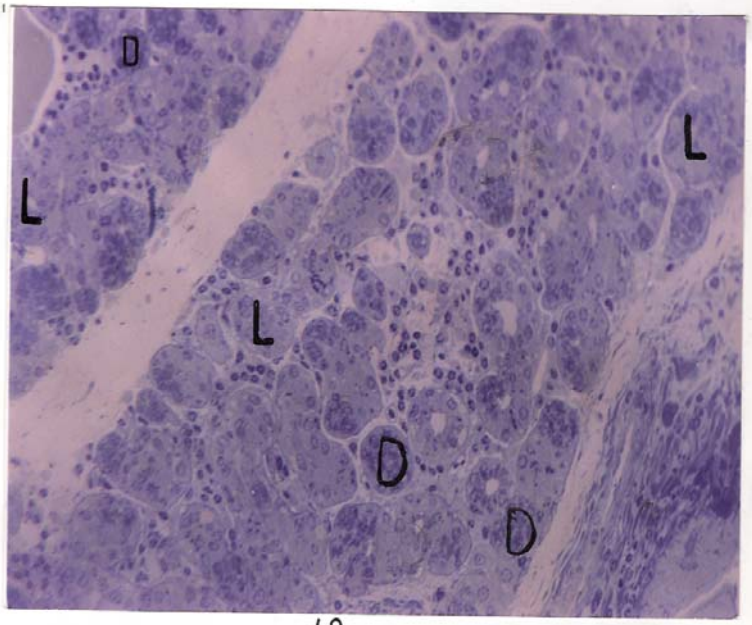

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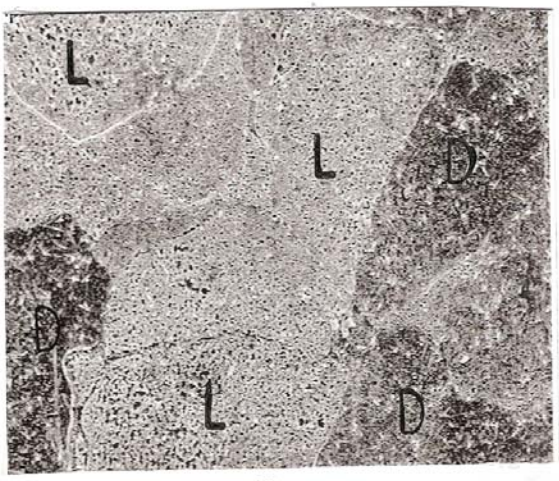
Figure 43: Scanning electron micrograph of the **corneal epithelium.** Epithelium cells form a polygonal mosaic on the surface of the cornea and they are divided into light cells (L) and dark cells (D).

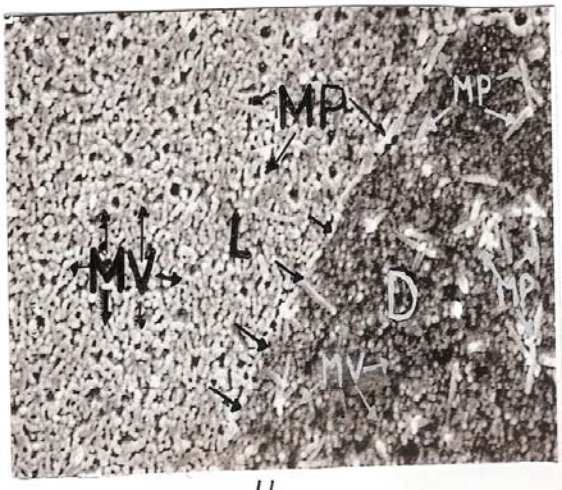
X 1500.

Figure 44: Scanning electron micrograph of the **corneal epithelium** showing the light cell (L) and dark cell (D) with microvilli (MV) and microplicae (MP). The cells are attached to each other by straight border (arrows).

X 5000.



43



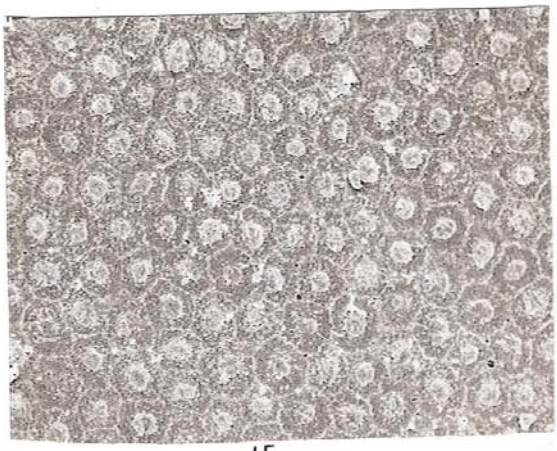
44

Figure 45: Scanning electron micrograph of the **corneal endothelium.** There is marked variation in endothelial cell size and shape and the cell borders are easy to see.

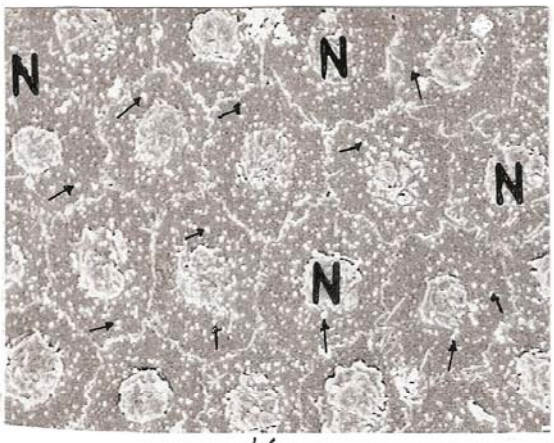
X 750.

Figure 46: Scanning electron micrograph of the **corneal endothelium** showing hexagonal pattern with few microvilli (arrows) on the surface. Note the large and centrally located nuclei (N).

X 2000.



45



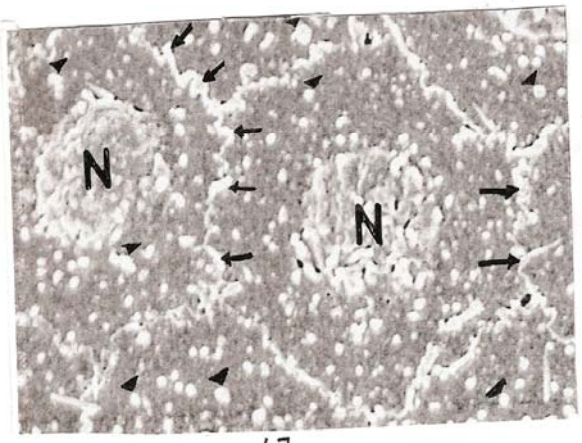
46

Figure 47: Higher magnification from figure 46 showing corneal endothelial cells with zigzag intercellular borders (arrows) marked by few microvilli (arrowaheads). Note the large and centrally located nuclei (N).

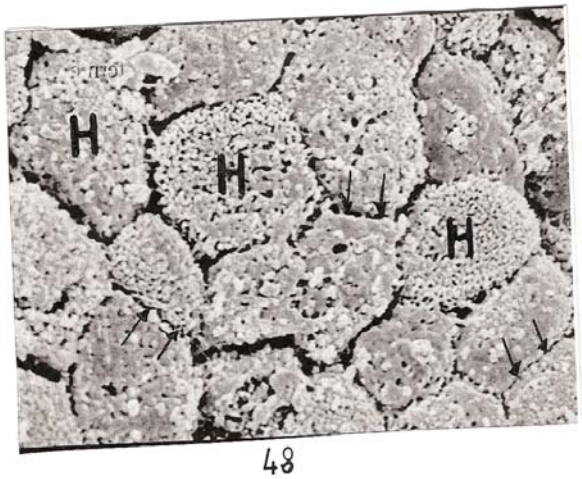
X 5000.

Figure 48: Scanning electron micrograph of the **retina**. The retinal pigment epithelium forms a mosaic pattern of hexagonal cells (H). The cell borders (arrows) are straight.

X 5000.



47



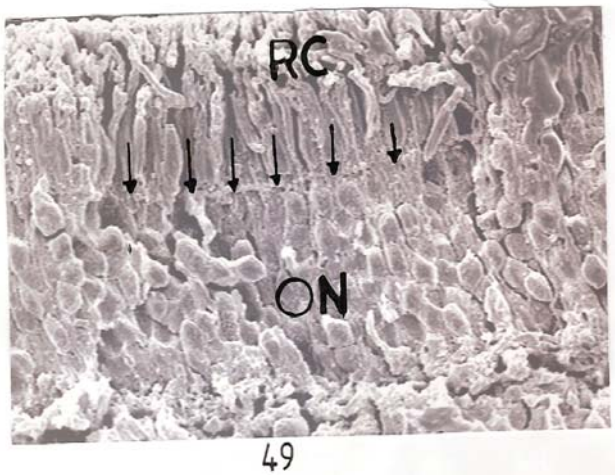
48

Figure 49: Scanning electron micrograph of the **retina** showing the photoreceptor rods and cones (RC), inner limiting membrane (arrows) and outer nuclear layer (ON).

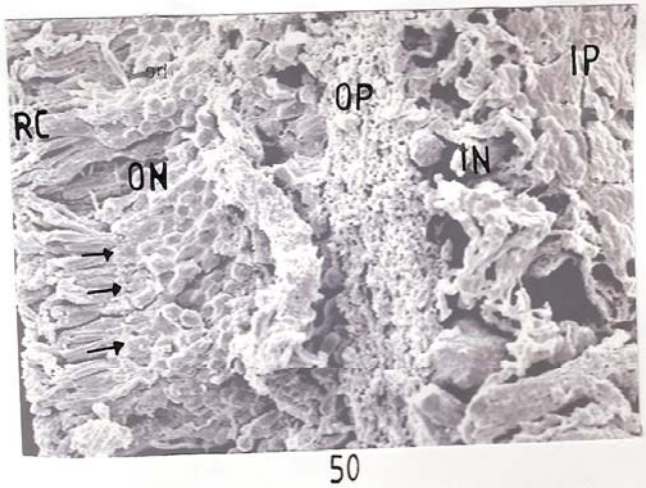
X 1500

Figure 50: Scanning electron micrograph of the **retina** showing the photoreceptor layer (RC), inner limiting membrane (arrows), outer nuclear layer (ON), outer plexiform layer (OP), inner nuclear layer (IN) and inner plexiform layer (IP).

X 1000.



49



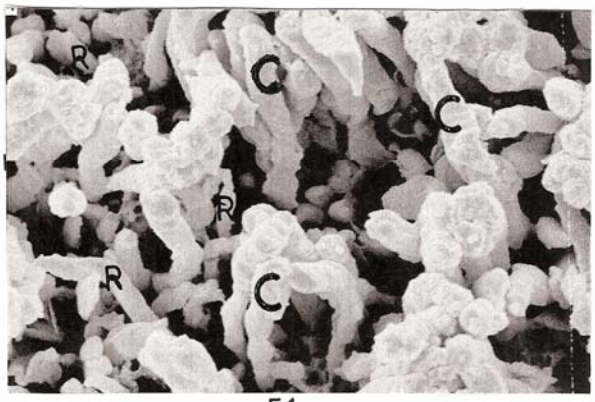
50

Figure 51: Higher magnification from figure 50 showing cones (C) and rods (R) which appeared as finger like bodies.

X 5000

Figure 52: Scanning electron micrograph of the **retina** showing the optic nerve fibre layer. Note the fasciculation of the nerve.

X 2000



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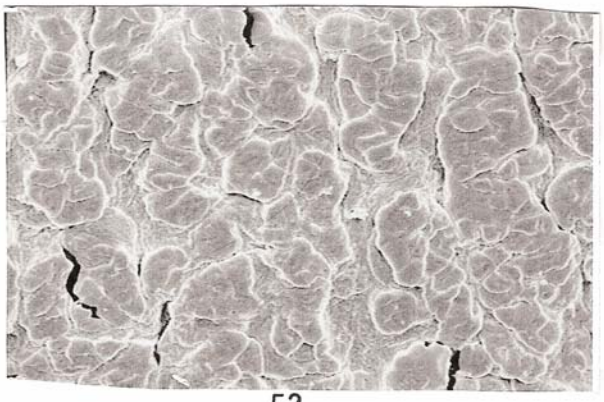


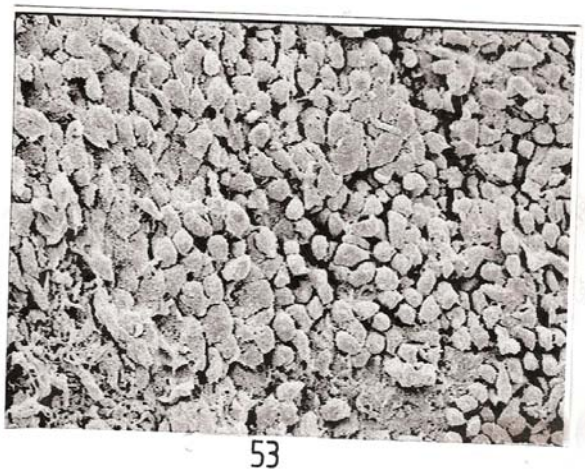
52

Figure 53: Scanning electron micrograph of the **third eyelid** showing a mosaic like pattern of polygonal cells.

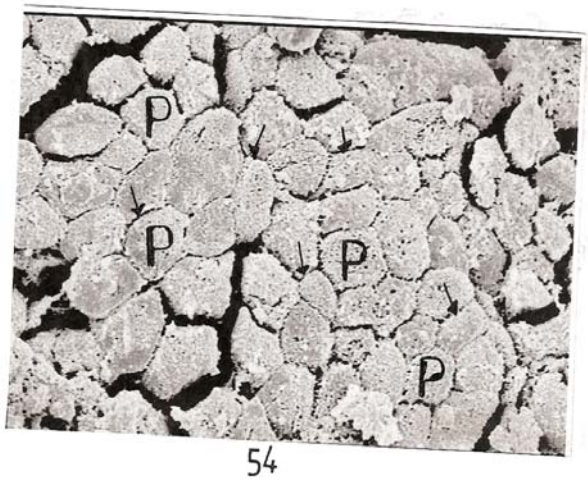
X 750

Figure 54: Scanning electron micrograph of the **third eyelid**. The epithelium of the third eyelid forms a mosaic pattern of polygonal cells (P). the cell border (arrows) is straight.

X 2000



53



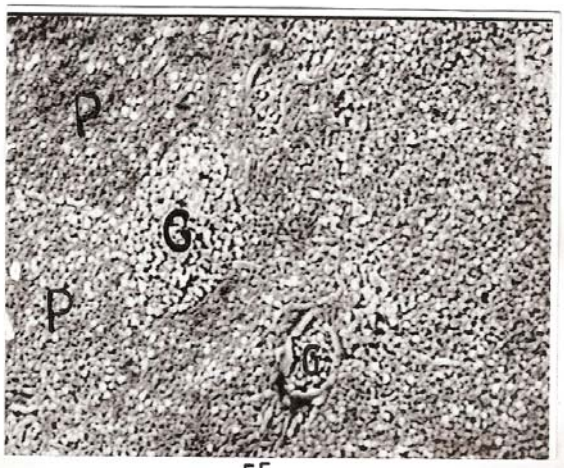
54

Figure 55: Scanning electron micrograph of the **third eyelid**. The epithelium showing polygonal cell (P) and goblet cells (G).

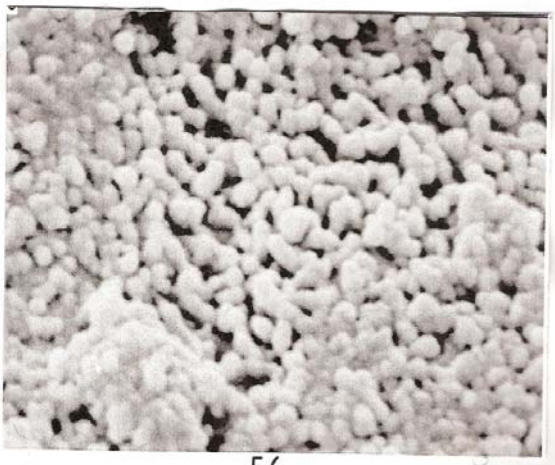
X 5000.

Figure 56: Higher magnification from figure 55 showing microvilli at the surface of the epithelial cells.

X 20000



55



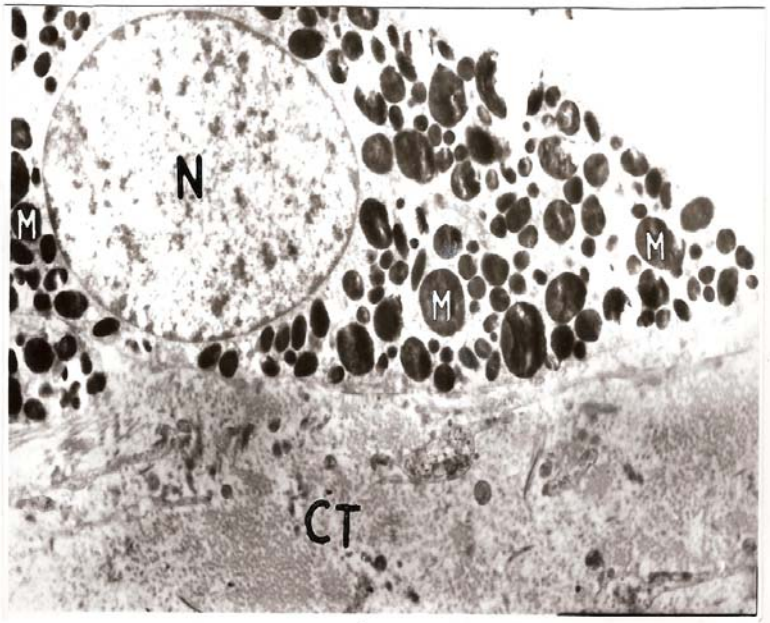
56

Figure 57: A transmission electron micrograph of the **choroid** demonstrating melanocyte in the connective tissue (CT). Its cytoplasm is crowded with melanin (M). The spherical nucleus (N) shows euchromatin.

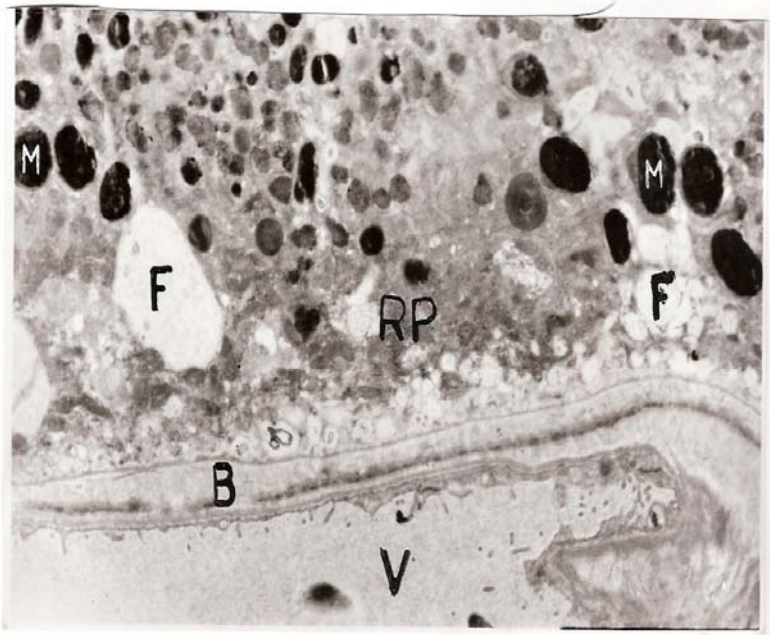
Lead citrate and uranyl acetate stain. X 4000.

Figure 58: A transmission electron micrograph of the **retina** showing the Bruch's membrane (B), blood vessel (V), retinal pigment epithelium (RP) consisting of melanin granules (M) and fat droplet (F).

Lead citrate and uranyl acetate stain. X 4000.



57



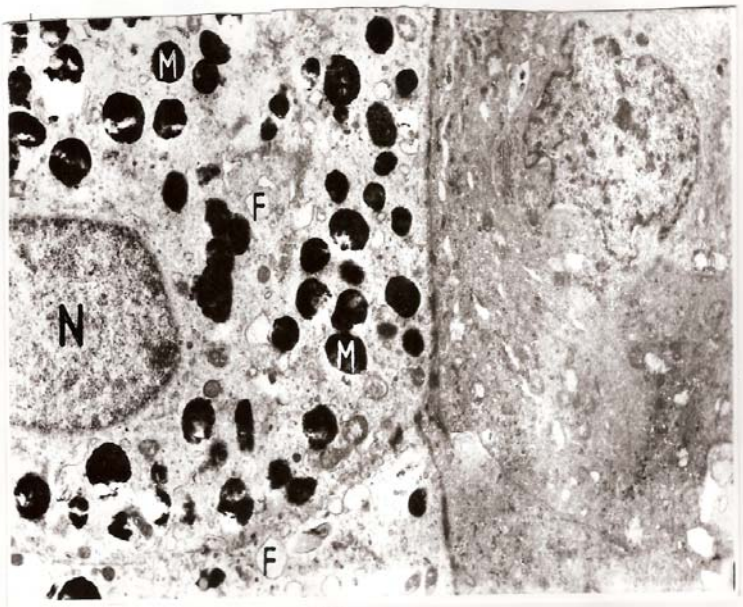
58

Figure 59: A transmission electron micrograph of the **retina** demonstrating part of retinal pigment cell consists of melanin granules (M) and fat droplet (F). The spherical nucleus (N) is also seen.

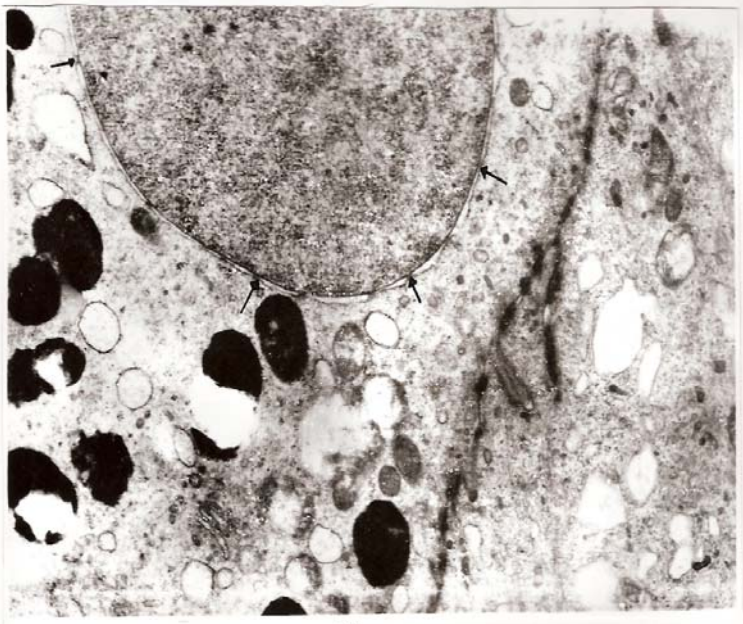
Lead citrate and uranyl acetate stain. X 4000.

Figure 60: A transmission electron micrograph of the **retina** showing the lateral margin of two adjacent retinal pigment epithelial cells joined by junctional complex. Note the presence of large number of nuclear pores (arrows).

Lead citrate and uranyl acetate stain. X 5000.



59



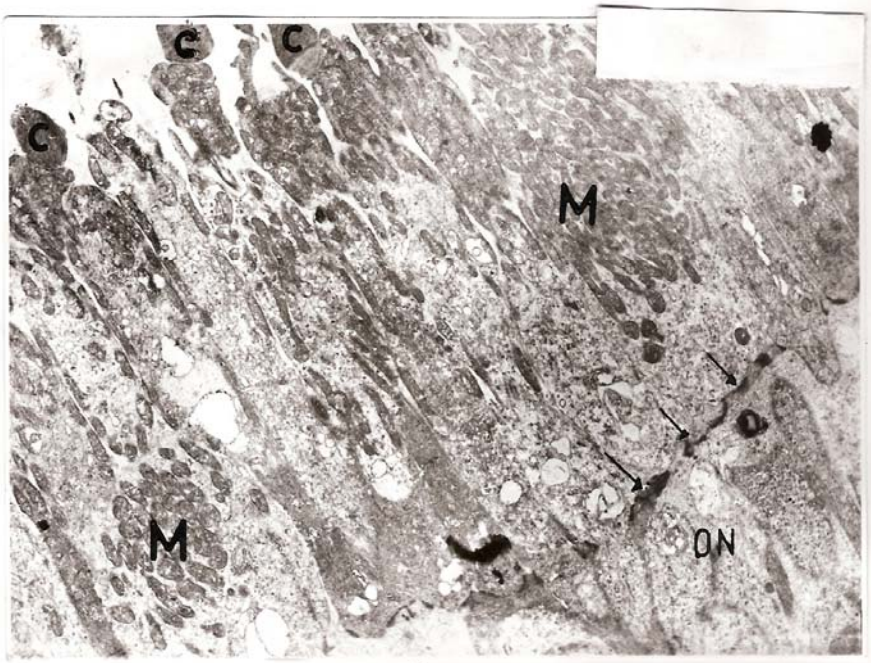
60

Figure 61: A transmission electron micrograph of the **retina** showing the inner segment of the rods and cones (C) with numerous mitochondria (M), outer limiting membrane (arrows) and part of outer nuclear layer (ON).

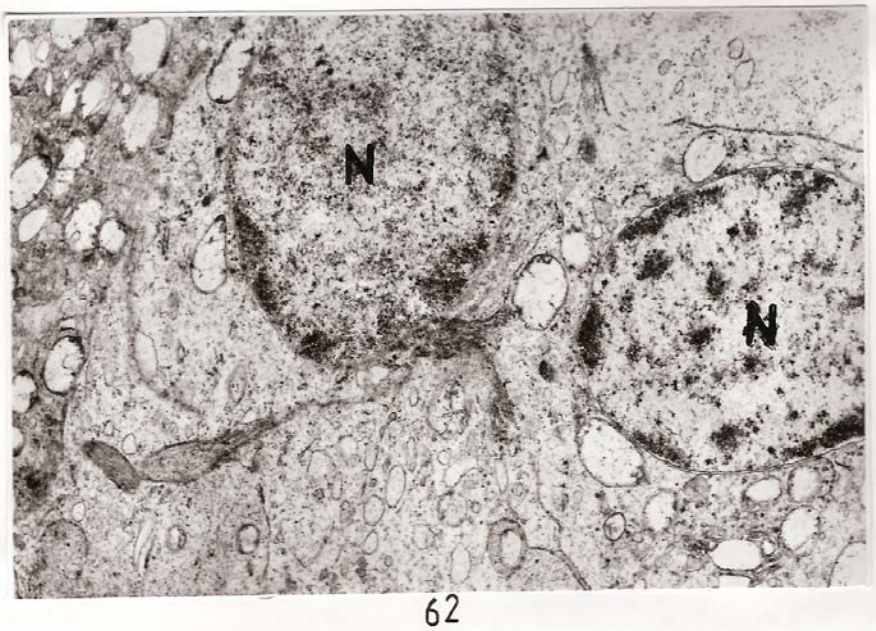
Lead citrate and uranyl acetate stain. X 5000.

Figure 62: A transmission electron micrograph of the **retina**. The outer nuclear layer showing parts of two cells with oval nuclei (N) with abundant heterochromatin.

Lead citrate and uranyl acetate stain. X 5000.



61



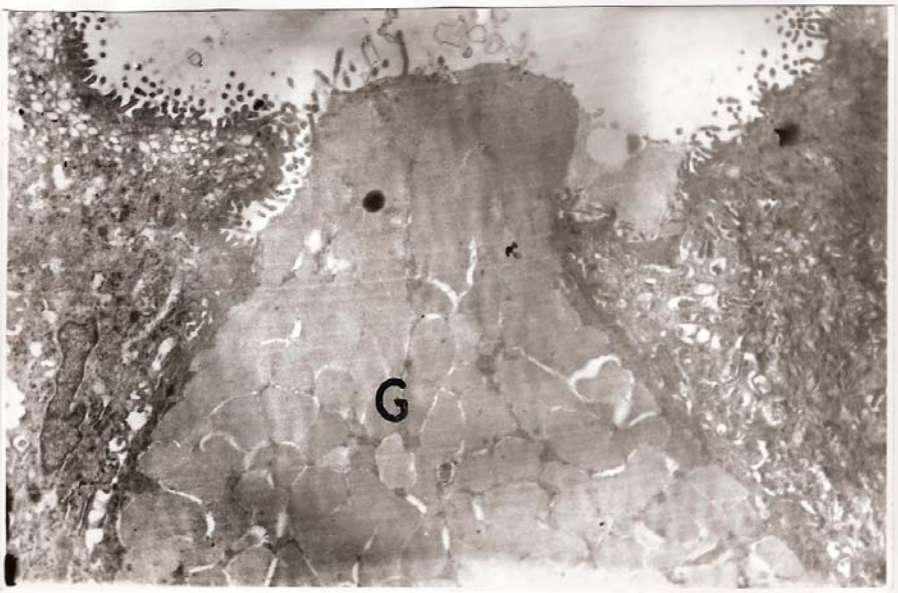
62

Figure 63: A transmission electron micrograph of the **third eyelid** demonstrating part of light goblet cell (G) extruding its mucous secretion into the cells surface..

Lead citrate and uranyl acetate stain. X 4000.

Figure 64: A transmission electron micrograph of the **third eyelid** showing part of light goblet cell (G) filled with mucigenous granules. The surface of the epithelial cells is provided with microvilli.

Lead citrate and uranyl acetate stain. X 4000.



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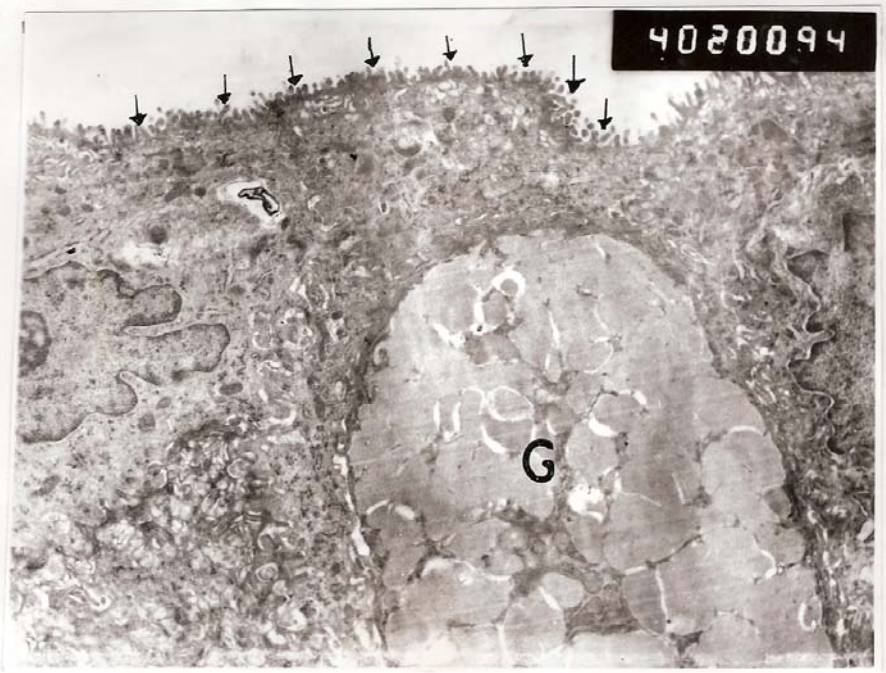
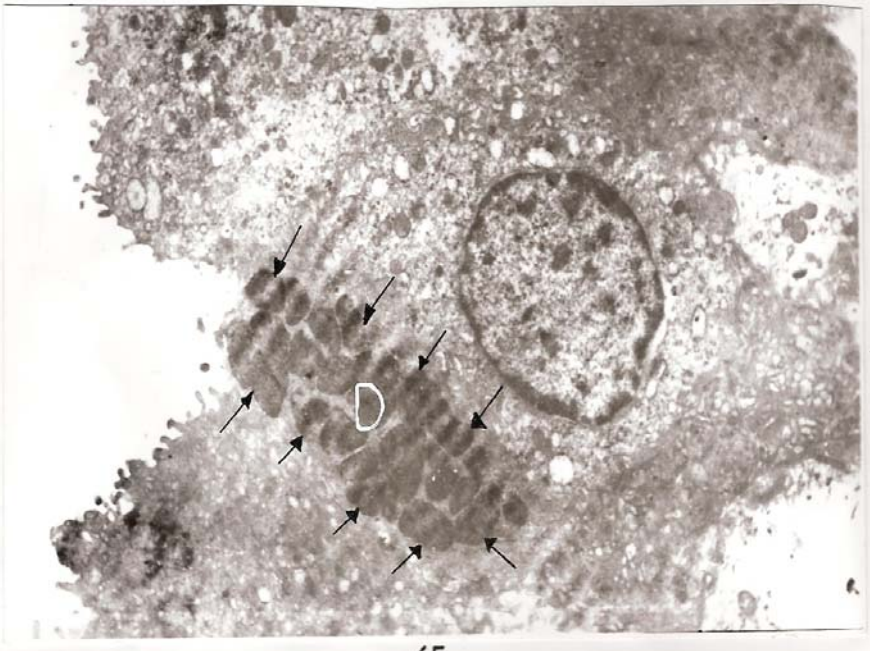


64

Figure 65: A transmission electron micrograph of the **third eyelid.** Part of dark goblet cell (D) containing dark granules (arrows).
Lead citrate and uranyl acetate stain. X 5000.

Figure 66: A transmission electron micrograph of the of the **third eyelid** demonstrating connective tissue (CT) and fibroblasts (F).
Lead citrate and uranyl acetate stain. X 4000.



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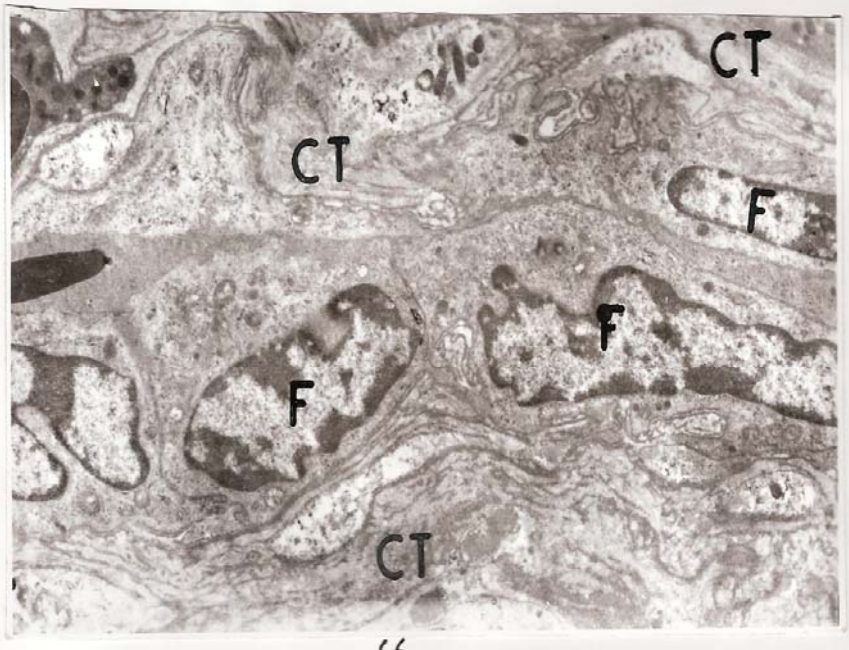

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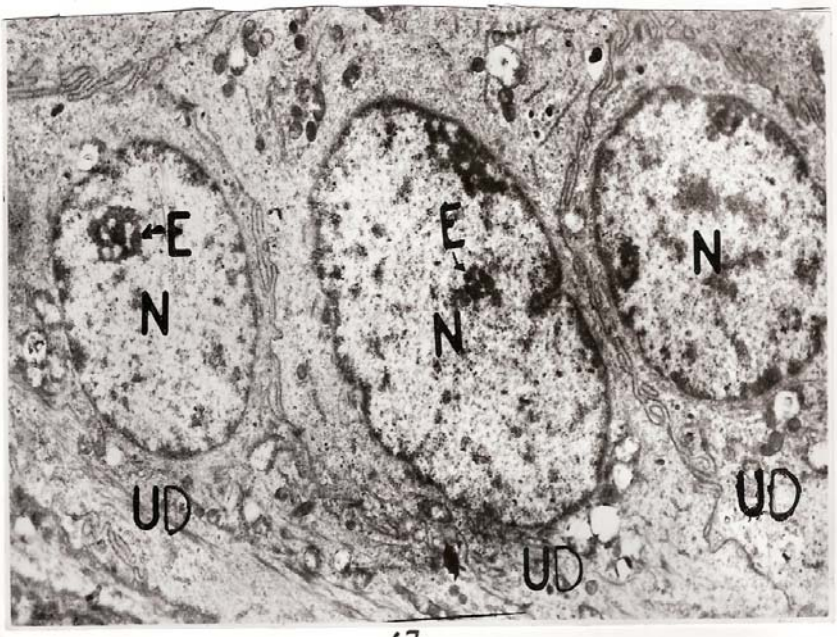
Figure 67: A transmission electron micrograph of the **superficial gland of the third eyelid** showing undifferentiated cells (UD) and spherical to oval nuclei (N) with a few heterochromatin and nucleolus (E).

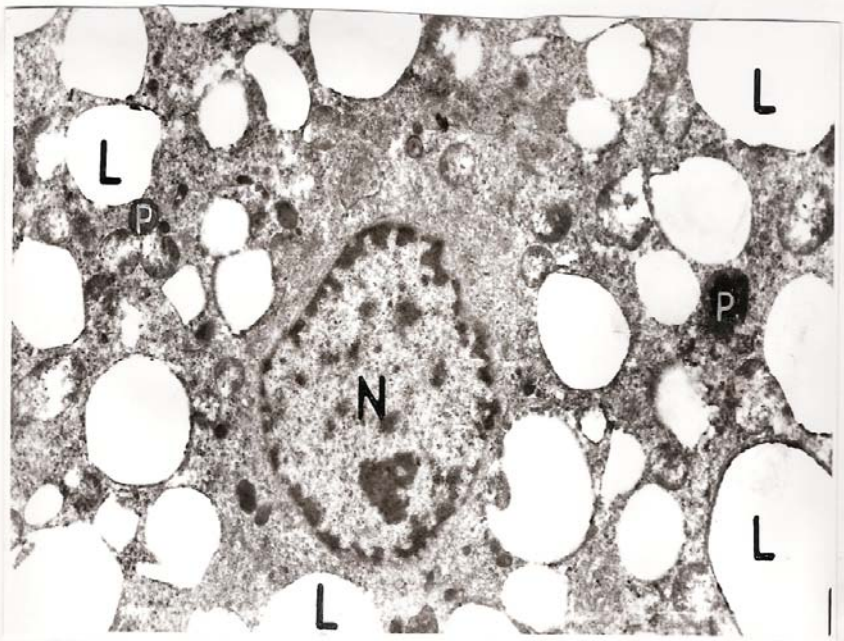
Lead citrate and uranyl acetate stain. X 4000.

Figure 68: A transmission electron micrograph of the **superficial gland of the third eyelid** showing differentiating cell consisting of numerous lipid droplets (L) and pigment granules (P). The spherical nucleus (N) has heterochromatin mostly attached to the nuclear membrane.

Lead citrate and uranyl acetate stain. X 5000.



67



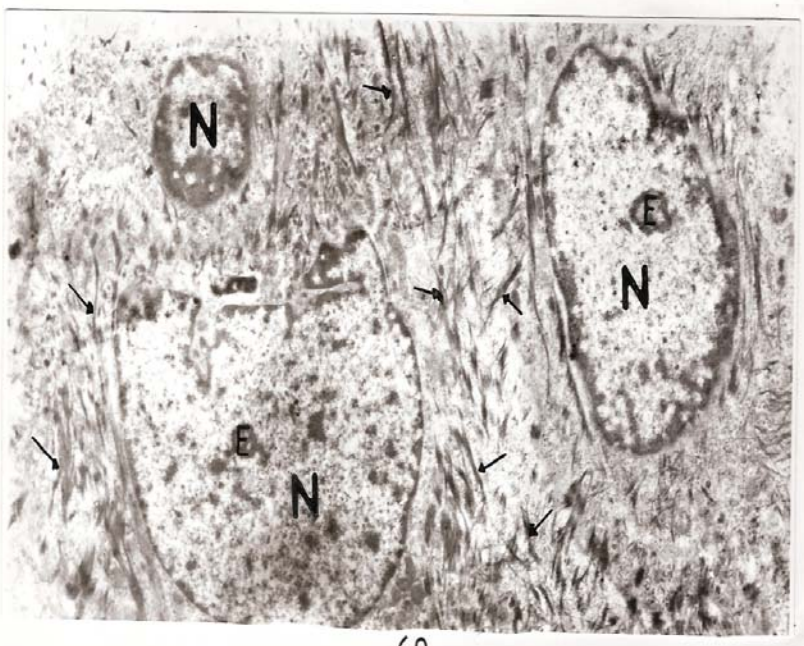
68

Figure 69: A transmission electron micrograph of the **superficial gland of the third eyelid** demonstrating undifferentiated cells consists of numerous filament (arrows). The oval nucleus with heterochromatin and nucleolus (E) are seen.

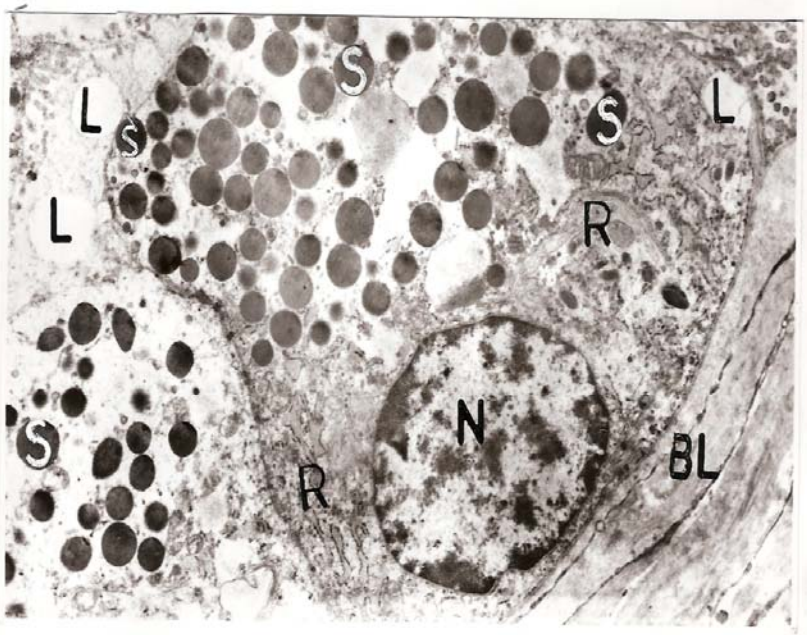
Lead citrate and uranyl acetate stain. X 4000.

Figure 70: A transmission electron micrograph of the **deep gland of the third eyelid** demonstrating part of a secretory cell surrounded by basal lamina (BL). The secretory granules (S) containing electron dense material in the apical cytoplasm. The spherical nucleus (N) with peripheral heterochromatin. Rough endoplasm reticulum (R) and lipid droplet (L) are also seen.

Lead citrate and uranyl acetate stain. X 4000.



69



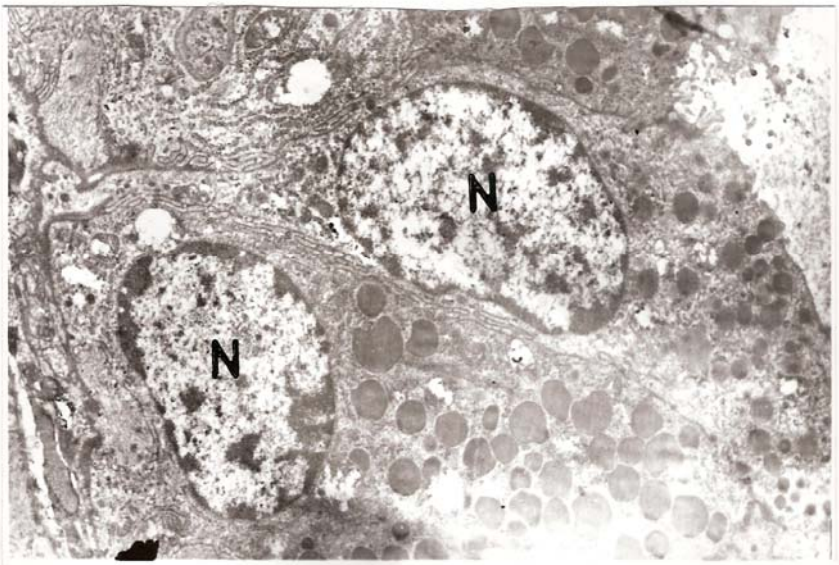
70

Figure 71: A transmission electron micrograph of the **deep gland of the third eyelid.** Two adjacent secretory cells showing secretory granules and the oval nuclei (N) have heterochromatin mostly attached to the nuclear membrane.

Lead citrate and uranyl acetate stain. X 4000.

Figure 72: A transmission electron micrograph of the **deep gland of the third eyelid.** Epithelial cells of Harderian gland duct showing notched nucleus (N) and pigment granules, and rest on basal lamina (arrows).

Lead citrate and uranyl acetate stain.. X 2700.



71

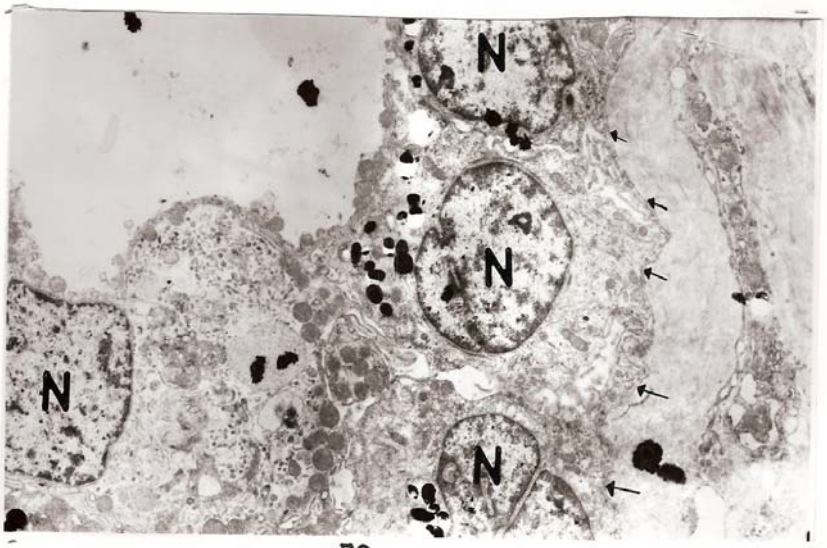


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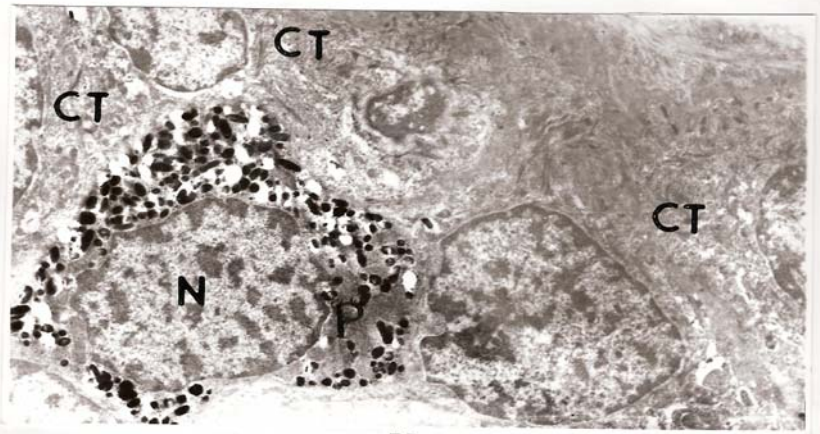
Figure 73: A transmission electron micrograph of the **deep gland of the third eyelid.** Pigment cell in the interstitial connective tissue (CT) containing melanin pigments. The oval nucleus (N) has peripheral heterochromatin.

Lead citrate and uranyl acetate stain. X 5000.



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