Reclassification of the sweat glands of the one-humped camel (Camelus dromedarius) as apoeccrine based on mode of secretion and extrusion

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Abstract

Background and aim of the study: Previous studies on the histology of the skin of the camel (camelus dromedarius) found the sweat glands opening into the hair follicle epithelium causing the reference to them as apocrine.

Other studies also declared that the animal only sweated in the neck region. If that is so, the question is, are the sweat glands also apocrine there or otherwise? The mode of secretion is another issue to ponder. If it is found to exist contrary to how it has been observed to be, a delpate on the classification is imminent prompting a possible reclassification, in the present work.

Methods: Histological studies were done on ten adult camels (six males and four females) from ten body sites, employing both routine staining techniques with haematoxyline and eosin (H&E), and special stains with polychromic methylene blue and also haematoxyline-phloxine-safran stain.

Results: In this study, apart from observing ducts opening into the primary hair follicles only, also found in the neck region, ducts of sweat glands opening directly onto the body surface, as

eccrine glands. The sweat gland fundus and duct in udder region also revealved bleb-like structures on the epithelial cells lining them, making one to ponder on the mode of secretion.

Conclusion: All put together, the work resulted in a proposed re-classification of the camel's sweat glands from being merely referred to as apocrine, to now be known as apoeccrine sweat glands.

Key words: Sweat glands, apocrine, eccrine, apoeccrine, necrobiotic

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Introduction

In earlier studies on camel skin, it was claimed that the camel had no sweat glands (Leonard,1894), but subsequent studies revealed their existence (Leese, 1927; Droandi; 1936; Curasson, 1947; Jararr and Faye, 2015; Dowling and Nay, 1962; Lee and Schmidt – Nielsen, 1962; Gbolagunte, 1983). They were observed to be simple, coiled, tubular glands seen in all body areas except in the skin of the upper lip, external nares, and perianal region (Dowling and Nay, 1962 Gbolagunte, 1983) and morphologically occupy a position intermediate between those of man and cattle (Lee and Schmidt-Nielsen, 1962). The glands of the camel, were observed to be more slender and more coiled than those of the cow, and are thicker and less coiled than those

of man. Their ducts were noticed to open into the neck of the cover (primary) hair follicles above the level of the sebaceous gland ducts.

The camel is known to have adapted effectively to its hot desert environment (Gbolagunte, 2016), and it has been established that some indices of adaption to the environment in domestic animals are the sweat gland density, shape (length/diameter ratio), and size (Jenkinson and Nay, 1968, 1972, 1973; Bligh, 1972; Amakiri and Mordi, 1975).

Sweat gland shape did not appear to reflect glandular activity since similar ranges of shape in cattle are found in different continents (Jenkinson and Nay, 1973). But, animals with large sac-like glands are initially at a greater advantage when sweating is required of them, since they carry large reserves (Nay, 1959), for there is a correlation between sweat gland shape and sweat gland volume (Nay and Hayman, 1963). Sweat gland volume in cattle is known to decrease in summer after heat exposure (Hayman and Nay, 1958; Findlay and Jenkinson, 1964) whereas, it was established that mean sweat gland volume has no direct effect on sweating rate (Amakiri and Mordi, 1975); rather, sweating rate was attributed to differences in sweat gland sizes and densities.

There is no evidence to indicate that sweating in the camel has an important role in maintaining body temperature just like in some species, like Kangaroo, sheep and pig where sweating plays an insignificant role in heat adaptation in contrast to cattle and man (Jenkinson and Nay, 1959) was however, asserted that temperature regulation, like water economy is an important adaptation aspect of the camel (Schmidt-Nielson, 1964)

Those who have found sweat glands in the camel have almost unanimously classified it as apocrine sweat gland, whose duct opens to the neck of the primary hair follicles; what in cattle is

referred to as epitrichial (Amakiri and Mordi, 1975). There is strong debate on whether the camel controls its body temperature by sweating or not. This brings us to the mode of secretion of the existing sweat glands, which may shed some light on why sweating as a means of temperature regulation in the camel has hitherto not been taken very seriously, and that is what this study has set out to address by examining the mode of secretion and extrusion, and if necessary reclassify.

Materials and Methods

Materials

Skin samples were obtained from ten adult camels (six males and four females) from Kano abattoir in Nigeria immediately after slaughter. They were taken from ten body sites. Some sites were common to both male and female. Others were exclusive to either male or female. The common sites were intended for a comparison between both sexes, while the sites exclusive to the male were meant for the study of those areas and could be assumed to be similar to those of the female. The sites exclusive to the female are those that female physiology may cause to show alterations in their structures.

Sites from which samples were taken

Common to Male and Female	Male only	Female only
1. Neck (dorsal)	1. Thigh	1. Ventral Abdomen
2. Hump	2. Breech	2. Udder
3. Back	3. Knee	
4. Midside	4. Upper lip	

Methods

Necropsy technique was adopted. Samples were spread out on corks and impaled in order to retain as far as possible their original size and shape.

Some of the samples were later fixed in 10% formal saline for 24hours dehydrated in 70% alcohol, wax impregnated, and sectioned vertically; and sometimes obliquely at 25 microns (u) with a rotary microtome serially, taking every fourth section for uniformity, and then stained with 0.5 polychromic methylene blue (Luna, 1968) for specific study of the sweat glands. Some of the samples were routinely stained in heamatoxyline and eosin (H&E). Some more samples remained in the formol-saline for 72 hours, and were later transferred to a 4% aqueous solution of phenol for three days to soften, then dehydrated in various grades of alcohol, cleared in benzene and wax-impregnated using Histokinnette tissue processor.

The tissues were embedded in paraffin. Vertical and horizontal sections were cut serially at eight microns with a rotary microtome. Sections from half of this group were stained using a simple triple stain, routine Heamatoxylene-phloxine-safran stain (Luna, 1968). The sections from the remainder of the group were routinely stained with heamatoxyline and eosine (H&E).

Results

Epidermis

The layers evident in all areas studied from the base of the epidermis to the surface were: stratum germinativum, stratum spinosum, stratum granulosum and startum corneum. The layer of stratum lucidum was only seen in the area where hair follicles were very scarce or absent such as the

smooth surface of the lip. In such areas, epidermal "peggings" were observed (Fig.1). The surface was characterized by very low ridges and grooves. The epidermal peggings which existed at the upper lip where there were only secondary hairs occurred at the adjacent portion to the point of the hair follicle. The epidermis was highly keratinized at the teat of udder (Fig.2),

male knee and upper lip.

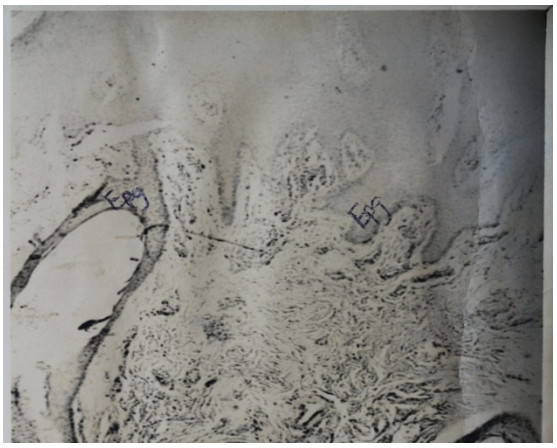

Figure 1: Carmel skin, upper lip (vertical section), Male: from below to the surface are the epidemal "peggings", (Epg) next to the hair follicle H & E X 120.

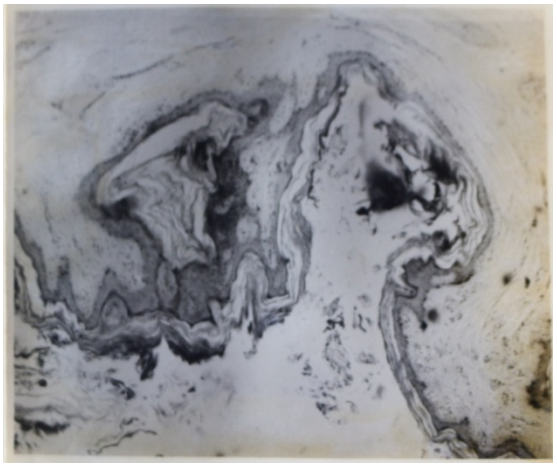

Figure 2: Carmel skin, teat of udder (oblique section) Female: Highly keratized epidermis. Haematoxyline – phloxine-Safran Stain X 300.

Dermis

Dermal papillae were prominent in the non-hairy portion of the upper lip, and were not present in hairy areas of the body. Below the epidermis, a thin superficial zone of delicate, closely woven fibers (Stratum papillare) were clearly evident in all the regions studied (Fig. 3) and an area with thick fibers (Stratum reticular) was observed.

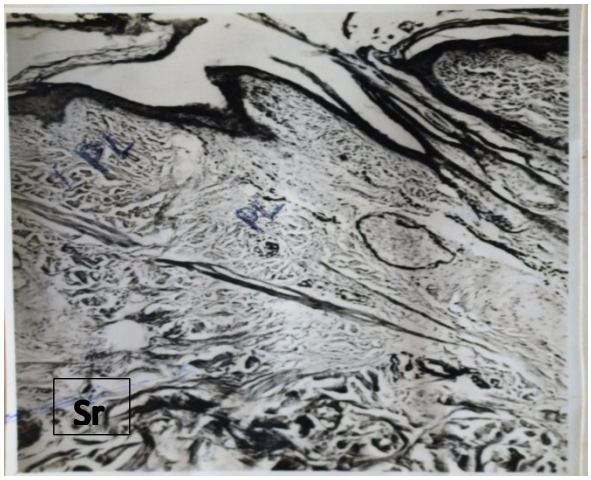

Figure 3: Carmel skin, midside (oblique section) Female: Stratum papillare (PL) below the epidermis, and a thick deeper area of Stratum reticulare (Sr). At the junction of the two, the arrector pili muscle attaches to the primary hair follicle. H & E X 120.

In all the body areas examined, the hair follicles were grouped into distinct clusters. These clusters, except at the knee were embedded in reticular connective tissue in groups (Fig 4), so that the hair grew in tufts (Fig.5).

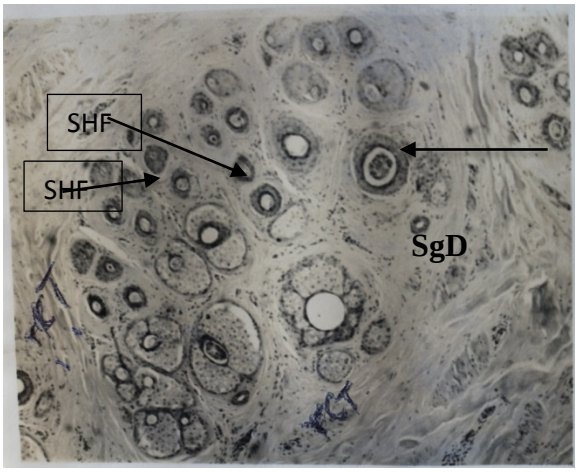

Figure 4: Carmel skin, back (horizontal section), Female: Hair follicle cluster surrounded by reticular connective tissue (rCT). Primary hair follicles at the base (arrows), with the associated sweat gland ducts (SgD). The secondary hair follicles (arrows) are at the top. H & E X 120.

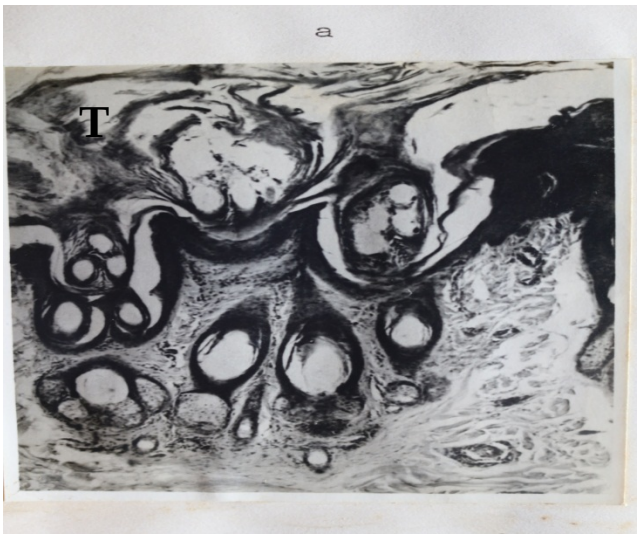

Figure 5: Carmel skin, midside (vertical section), Male: shows hairs growing in turfts (T). H & E X 300.

The typical simple or branched saccular sebaceous glands of the holocrine type surrounded each primary hair follicle, and each had its own ring of such glands (Fig. 6).

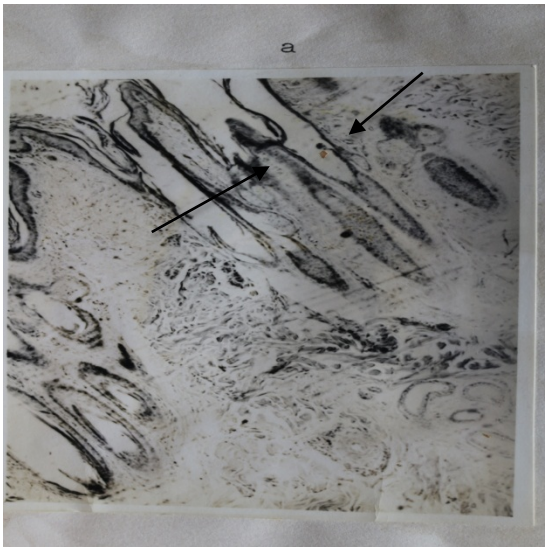

Figure 6: Carmel skin, midside (oblique section), Male: simple branched saccular sebaceous glands (arrows) around both types of hair follicle (secondary and primary). Haematoxyline – phloxine-Safran Stain X 300.

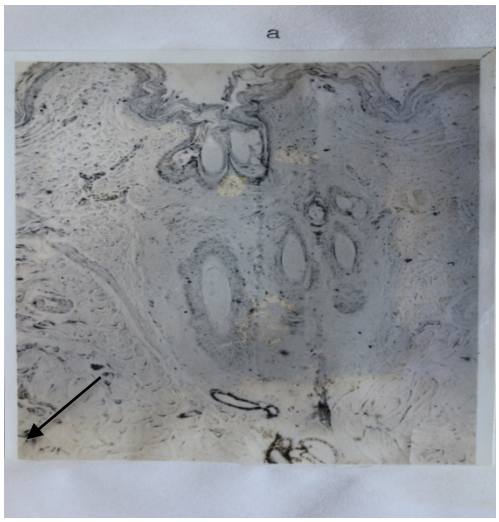

Figure 7: Carmel skin, Ventral abdomen (Vertical section), Female: Sweat gland secretory portion (arrow) exists in relation to the primary hair follicle. H & E X 120.

Simple coiled tubular sweat glands were observed in sections from all body areas studied except in the skin of the upper lip. These tubular glands were seen in association with the larger primary (cover) hair follicles only, and none was seen related to the follicles of small secondary hairs.

The figure illustrates a portion of the spiraled secretory portion and an oblique section of the associated duct. The secretory portion in the udder showed bleblike protrusion of the apical portions of the epithelium retaining low columnar epithelial cells (Fig 8).

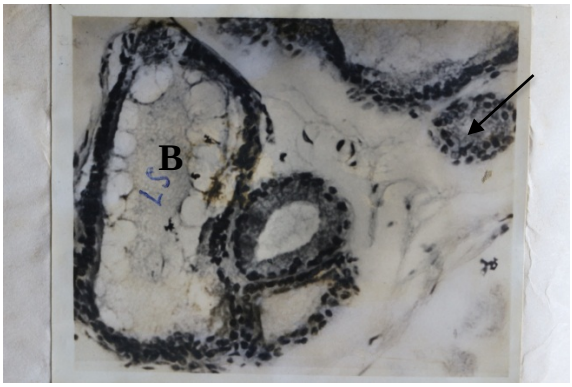

Figure 8: Carmel skin, Udder (transverse section), Female: Bleblike protrusion (B) of the apical portions of the epithelium which retains the low columnar epithelial cells. The luminal secretions(LS) in the fundus. The two-layered epithelial cells of the sweat gland duct are seen at upper right (arrow). Polychromic Methylene Blue X 600.

Secretions (LS) were observed in the lumen. Two-layered epithelial cells were observed close to the duct. In the neck region, the sweat gland ducts were observed coursing close to the hair follicles to open directly onto the surface of the epidermis (Fig 9).

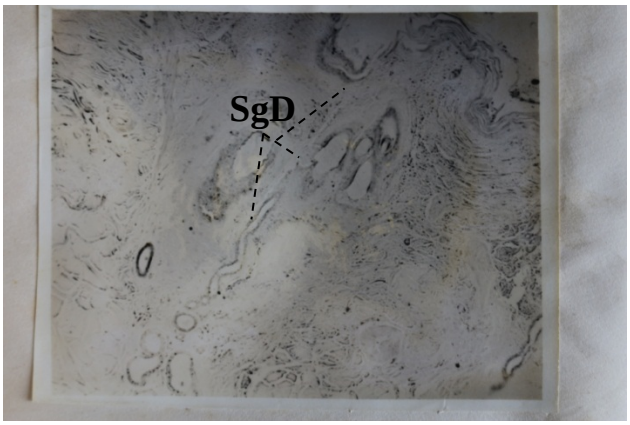

Figure 9: Carmel skin, neck (oblique section), Female: The spiral course of the sweat gland duct (dotted arrows), opening directly onto the surface of the skin. H & E X 120.

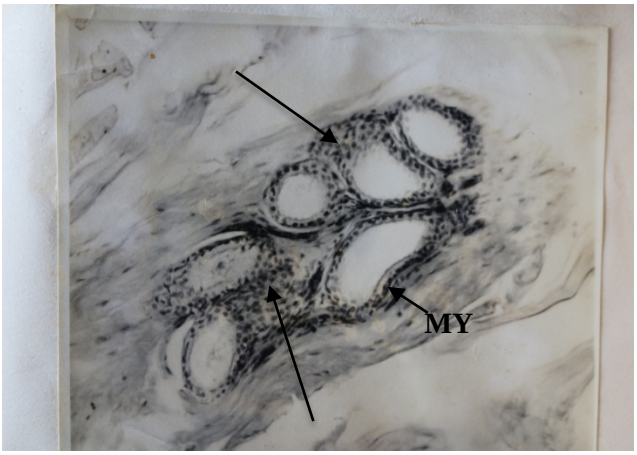

Figure 10: Carmel skin, Breech (transverse section), Male: The Spiralled, expanded secretary portion of the sweat gland finally ending in a loose serpentine net (arrows). Myoepithelial cells(MY) are at the base of the columnar epithelium. Polychromic Methylene Blue X 600.

The figure showed the sweat glands ending in serpentine nets.

Discussion

The epidermis of the camel skin did not vary from the general pattern that has been described for domestic animals (Jenkinson, 1965; Jararr and Faye, 2015). In the dermis however, sweat glands usually appear deeper than expected. Dowling and Nay (1962), in supporting Leonard'(1894)'s failure to detect sweat glands in the camel, claim that the glands in the camel are deeper than in other species of animals, making it easy to miss in sections. In this study however, it was found that the sweat glands were not too deeply situated in the skin of the neck where the duct was observed opening directly on the skin surface. This may be why Cleland (1909), thought that camels perspired only on the back of the neck. The glands whose ducts course directly to the surface in this study's neck region, were usually histologically not too deep into the dermis (Gbolagnte, 1983).

Mammalian atrichial (eccrine) and epitrichial (apocrine) sweat glands are variously coiled (Amakiri and Mordi, 1975). Morphologically the sweat glands of the camels, appear to occupy a position intermediate between those of man and cattle (Dowling and Nay, 1962). Accordingly, the glands of the camel, though more slender and more coiled than those of the cow, are thicker and less coiled than those of man. They were referred to as simple coiled tabular sweat glands (Lee and Schmidt Nielsen, 1962).

Jenkinson (1967), classified the tubular skin glands of mammals as consisting of two functional types: merocrine and holocrine. In the real sense, the sweat glands are a type of eccrine glands which are glands that produce and secrete substances unto an epithelial surface by way of a duct. There are two main types of sweat glands that differ in their structure, function, secretory product, mechanism of excretion, anatomic distribution, and distribution across species (Wilke et

al., 2007). It was distinguished by its morphological appearance during the process of secretion, its development and its position (Jenkinson, 1967). An apocrine gland was defined as (1) developing from the hair anlage in the embryo, (2) always being situated beside or associated with a hair follicle, and (3) exhibiting two phases of secretion – "necrobiotic; involving partial degeneration of the secretory epithelium, and "simple". The eccrine gland in constrast was defined as one which (1) originated directly from the primitive epidermis (2) was not associated with a hair follicle, and (3) did not exhibit necrobiotic secretion.

Furthermore, the sweat glands of the general body surface of man and certain primates, and in specialized areas of some mammals such as foot pads of the cat or dog are believed to be eccrine while those in the specialized areas of man e.g. axilla and in the skin of most haired mammalia are believed to be apocrine. This classification and distribution of sweat glands is still generally accepted, although some doubts have been expressed regarding its validity (Montagna and Parakkal, 1974).

But there is no unequivocal physiological evidence for the existence of a necrobiotic secretory cycle in the sweat glands of man or any other species. The presently accepted view of apocrine secretion is based mainly on the presence (after histological and histochemical processing) of cellular configurations in large sweat glands of human axilla (Jenkison, 1967). These configurations have been interpreted as representing different stages of necrobiotic cycle in which the epithelial cell increases in size from cubical to columnar; the luminal apex forms a bleb which breaks off to form the secretion (as seen in this study), and the cell finally reverts to its original cubical form (Jenkinson, 1967).

As presently observed here in the camel, there are both types of sweat glands. In all the body areas studied, the sweat gland ducts were observed to open into the neck of the primary hair follicle above the level of the sebaceous gland ducts just like the apocrine type. However, in the skin of the neck region, the ducts were seen to open sometimes into the primary follicles as in all other sites and sometimes seen to open directly onto the skin surface, thus indicating a probable eccrine type.

It is therefore, here suggested that the sweat glands of the camel, instead of being referred to as mere apocrine (Dowling and Nay, 1962; Lee and Schmidt-Nielsen, 1962), be reclassified. If it is to be called merocrine, as earlier suggested (Gbolagunte, 1983) – because it is mainly apocrine – it should be borne in mind that some have classified merocrine as being also known as eccrine. It may not, therefore, be too appropriate to classify the camel's sweat glands as such.

The secretory portion of the sweat gland at the udder revealed bleblike protrusion of the apices of the epithelial cells, thereby representing a different stage of a "necrobiotic" cycle which was described as apocrine type of secretion (Jenkinson, 1967). This interpretation was disputed (Montaga and Parakkal, 1974), and asserted that the mechanism of secretion does not involve rupture of the cell membrane; considering it as a "simple" form of secretion. The retention of the low columnar shape by the epithelial cells in the sweat glands at the udder of this study in the camel supports the latter view. Some human sweat glands cannot be classified as either apocrine or eccrine, having characteristics of both; such glands are termed **apoeccrine** (Wilke et al., 2007). They are larger than eccrine glands, but smaller than apocrine ones. Their secretory portion has a narrow area similar to secretory coils in eccrine glands.

Apoeccrine glands, found in the armpits and perianal regions of man, have ducts opening onto the skin surface (Wilkke et al., 2007). They are presumed to have developed in puberty from eccrine glands and can comprise of up to 50% of axillary glands. Apoeccrine secrete more sweat than both eccrine and apocrine glands, thus playing a large role in axillary sweating. Apoeccrine glands are sensitive to cholinergic activity though they can also be activated via adrenergic stimulation. Like accrine glands, they continuously secrete a thin, watery sweat (Wilkke et al., 2007).

The claim that camels visibly perspire only over a small area on the back of the neck (Cleland, 1909), could be justified by the present finding of eccrine type of sweat glands in the neck region. Direct opening, might mean direct expulsion of sweat at a probably faster rate than through the hair follicles. The fact that shorn camels were found to sweat freely than unshorn camels (Schmidt-Nelsen et al., 1957), means that expulsion of sweat, onto the skin surface, without any obstruction by the hair was quicker and apparently more profuse.

Rollinson et al., (1972), observed nerve trunks in the papillary layer which ramified peripherally in close association with blood vessels and innervated the epidermis, the component of hair follicle unit and blood vessels. This study did not reveal any evidence of sweat gland innervation: accordingly, the low water loss from camel skin (Schmidt-Nelson, 1964), suggests that the thermal sweating response of this species may be less efficient than that of the horse, sweat gland of which is highly innervated. The camel depends more on heat storage in warm conditions creating a gradient on the skin surface preventing heat gain (Schmidt-Nelson and Schmidt-Nelson, 1957).

On the basis of all these assertions, rather than classify the camel skin as merocrine as earlier suggested elsewhere (Gbolagunte, 1983), it is hereby proposed in this study, that the camel sweat glands be referred to henceforth, as **apoeccrine,** having been evidently shown to possess both eccrine sweat glands especially in the neck and apocrine sweat glands in other hairy regions, where they exist epitrichially.

Conclusion

The histological study of various body regions of the skin of the camel (Camelus dromedarius) revealed that the ducts of the sweat glands opened into the epithelium of the primary hair follicles above the level of the sebaceous gland ducts as in apocrine glands of domestic animals, but in the neck region, some opened into the primary hair follicle ducts, and some directly onto the surface of the skin epithelium as in eccrine glands in man. The epithelial cells of the secretory portions of the glands as well as those of their ducts in the udder, also showed bleb-like protrusions into the lumen, exhibiting a necrobiotic phase of secretion as in apocrine glands; while those in the neck only showed normal low columnar epithelium depicting “simple” type of secretion as in eccrine glands.

These observations prompted a re-think on the classification of the camel’s sweat gland from mere apocrine as in other domestic animals, especially cattle with its epitrichial apocrine sweat glands, to **apoeccrine** sweat glands since it also has eccrine glands in the neck region.

Acknowledgments

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