ENCAPSULATED NERVE ENDINGS IN THE DIGITAL PADS AND PLANUM NASALE OF DOGS AND CATS

by

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INTRODUCTION

The histological structures of the encapsulated nerve endings in the skin of mammals is not a new scientific discipline. The study of these endings began as early as 1741 when Vater discovered a lamellated corpuscle during the course of his dissection studies. This went unnoticed until 1836 when Pacini confirmed the findings of Vater. Since then, as quoted by Winkelmann (30), the corpuscle has been designated as the Vater-Pacini corpuscle.

In the year 1860 Krause and his co-workers (14), found an end bulb in the skin of mammals and noted a similar structure in the skin of the cat. Merkel (16) found tactile cells and corpuscles in the cat's paw. Sfameni (22) found that the corpuscle of Vater-Pacini was similar in both man and cat.

In 1941, Weddell (25) working on the skin taken from the pad of the thumb of a rhesus monkey found that a cutaneous nerve plexus was disposed in two main layers. Arising from the superficial layer were fibers of which each had one or more endings. The end organs borne by a single fiber arising from the cutaneous nerve plexus were always of the same type. The following types of nerve endings were identified 1. Meissner's corpuscles, 2. Merkel's discs, 3. Krause end bulbs and 4. Nerve networks situated immediately beneath the epidermis. Fine terminal fibers arose from the net and ended beneath and between the cells of the deep layer of epidermis. The study of Weddell was the first modern approach in the study of neurohistology of the skin but he did not include cats in his study.

Winkelmann (30, 31, 32) working on the skin of man and cat has reported extensively on the subject and has renamed the Krause's end bulb as the mucocutaneous end organ mainly because of two reasons. In the first instance

these nerve endings exclusively occurred in the dermis at the mucocutaneous junction and secondly he found that the end bulb did not present an inner bulb. The end organ consisted of a connective tissue capsule which was not well defined and was merely the condensation of the surrounding connective tissue fibers of the area around the end organ. The myelinated nerve fibers on entering the organ gave off a number of branches but did not anastamose with other fibers.

The main purpose of this study was to investigate and compare the encapsulated nerve endings in similar areas in the glaborous skin of the cat and the dog and to find the presence of mucocutaneous end organs in the dog at the mucocutaneous junction. The areas compared in this study were skin from the regions of the digital pads and planum nasale.

MATERIALS AND METHODS

Six canines of mixed breeds, three males and three females and six felines of mixed breeds, three males and three females were utilized for this study. Foot pads (digital pads) and the skin from the region of the planum nasale were removed within one-half hour after euthanasia of the animal.

Fixation: The representative pieces of tissue were fixed in a solution containing

1. 5.0 mls. of formalin
2. 2.0 grams of trichlor-acetic acid
3. 90.0 mls. of 80 percent isopropyl alcohol.

The tissue specimens were left in the above solution for seven days after the method of Bodian (3).

Dehydration, embedding and sectioning: The tissues were dehydrated and

embedded in paraffin with the help of the auto-technicon. Sections were cut at 20 micra thickness and were mounted on slides previously smeared with Meyer's albumin.

Staining: The sections from both the regions of all the animals were stained by the Bodian (2) method given below.

1. Paraffin was removed by placing the sections in two changes of xylol.

2. Sections were run in sequence through the following: Two changes of absolute ethyl alcohol, 95 percent ethyl alcohol, 80 percent ethyl alcohol, 60 percent ethyl alcohol to distilled water.

3. They were then placed in a solution of one percent protargol (silver albuminose), containing 5.0 grams of metallic copper per 100 mls. of solution. The metallic copper was initially treated with aqua regia for the removal of impurities and then was thoroughly washed in distilled water. The sections were allowed to remain in this solution for 24 hours at a constant temperature of 37 degrees centigrade.

4. Sections were washed by running them in three changes of distilled water.

5. Sections were then transferred for 5 minutes to a reducing solution containing the following ingredients:

1.0 gram of Hydroquinone,

5.0 gram of Sodium Sulphide

100.0 mls. of distilled water.

6. Toning was carried on after washing the sections in three changes of distilled water by placing them for 2 to 5 minutes in a solution of one percent gold chloride containing three drops of glacial acetic acid

per 100 mls. of solution. By this treatment the sections were decolorized. In some instances the sections turned grey in which case step No. 8 was avoided.

7. Sections were then washed again in distilled water.

8. The sections were placed in one percent oxalic acid for one-half minute. By this treatment the sections developed a faint purple or a bluish tinge.

9. Sections were washed in three changes of distilled water.

10. The residual silver salts were removed by placing the sections in a solution of five percent sodium thiosulphate for 5 to 10 minutes.

11. The sections were then washed in distilled water.

12. Sections were run through 80 percent ethyl alcohol, 95 percent ethyl alcohol, two changes of absolute ethyl alcohol and two changes of xylol.

13. They were finally mounted in Canada balsam and covered with cover slip.

Bodian (3) recommended counterstaining with one percent eosin, hematoxylin and eosin or Mallory's stain. This step was completely avoided as the nerve endings and the background appeared less sharply defined. A few sections from each tissue specimen however were counter stained with one percent aniline blue in which the background stained lightly.

Five hundred tissue sections were cut, mounted and studied. Rapid silver impregnation method or Ammoniacal silver method (Winkelmann, 1955), was not followed.

Measurements of the dimensions of encapsulated nerve endings were made with the ocular micrometer. The ocular micrometer was caliberated for both

low and high power objectives of the microscope used for this study with the aid of the stage micrometer.

REVIEW OF LITERATURE

Wagner and Meissner in 1852, as quoted by Weddell et al. (27), were the first to describe a cutaneous nerve end organ in the relatively avascular papillae of the human finger pad and called it "Taskorperchen". Meissner also suggested that the axon ended freely within the capsule in a slight terminal swelling. Subsequently many scientists agreed with this view.

Sabotta (20), described the Meissner's or Wagner's corpuscles as elongated ellipsoidal bodies 60-150 microns by 30-60 microns with a distinctly striated appearance. The structure of the corpuscle consisted of flat tactile cells piled up one on the other, with flattened nuclei between which were found the terminal fibrillar expansions of the axis cylinders of the nerve fibers. Two to five fibers entered the lower part of the capsule.

Cauna (6), stated that the Meissner's corpuscles in the papillae of the human finger pad were elongated in confirmation to the shape of their surroundings.

Trautman and Fiebiger (24), stated that the Meissner's corpuscle was provided with a thin connective tissue capsule, which was continuous with the perineural sheath of the nerve fibers, and contained transversely arranged tactile cells. The striated appearance of the corpuscles was due to the arrangement of the nuclei and to the spiral turns of the one to five myelinated fibers. The nerve fibers lost their sheaths and terminated as branched naked axis cylinders with expansions on the tactile cells. Bundles of fibrils sometimes emerged from the corpuscle and terminated intra-epithelially or

jointed the neighboring corpuscle. The shape of Meissner's corpuscle was described as resembling a fur cone. The corpuscles were 100 micra in length, 25-30 micra wide and were located in the papillae of the papillary body on the palms and soles of the human skin. They described the presence of Meissner's corpuscles in domestic mammals too.

Weddell et al. (27), demonstrated that myelinated stem axons left the cutaneous nerve plexus and pursued a simple or complicated, often a tortuous, course within the capsule. The axons gave rise at intervals to fine, naked axoplasmic filaments which terminated freely among the cells of the corpuscular wall.

Maximow and Bloom (15), described Meissner's corpuscles as located in the cutaneous papillae of the skin of the palms, soles and tips of the fingers and toes. They were elongated with the long axis vertical to the surface and pear-shaped or elliptical formations with rounded ends.

Table 1. Dimensions of the Meissner's corpuscles as indicated by various scientists.

S. No.	Name of Scientist	Length of the Corpuscle	Width of the Corpuscle
1.	Satterthwaite (21)	0.1 mm	-
2.	Bohm et al. (5)	100-180 microns	45-50 microns
3.	Piersol (17)	45-140 "	35-55 "
4.	Sabotta (20)	60-150 "	30-60 "
5.	Maximow and Bloom (15)	40-100 "	30-60 "
6.	Trautman and Fiebiger (24)	100 "	25-30 "

Krause end bulbs were described by William Krause and his pupils (14), their observations included a number of animals and regions in the body.

Cats were included in their study but not dogs.

Trautman and Fiebiger (24) state that the mammalian end bulbs were cylindrical. The nerve fiber on entering the bulb, lost its myelin and penetrated almost the entire length of the finely granular and concentrically arranged inner bulb. The end of the fiber was either rounded off or expanded into an ending consisting probably of a dense network of neurofibrils. The capsule consisted of two to five concentric connective tissue lamellae with flat nuclei. They were present in the skin and the adjoining mucous membranes, and in the conjunctiva and the tongue.

Rao (18), in his studies on the nerve endings of the genitalia of the bovine found the Krause end bulbs to be oval encapsulated bodies, lamellated in structure and located in the superficial layers of the subepithelial connective tissue of the glans penis in the male bovine and in the clitoris, vestibule and the labia of the female bovine. Sizes of the end bulbs varied in different locations (vide Table No. 2).

Table 2. Dimensions and locations of the Krause end bulbs as given by various scientists.

S. No.	Name of Scientist	Species	Location	Length of the Corpuscle	Width of the Corpuscle
1.	Bohm et al. (5)	-	-	(a) .02-.03 mm.	.015-.025 mm.
				(b) .045-.1 mm.	.02 -.08 mm.
2.	Satterthwaite (21)	-	-	0.05 mm. in diameter	
3.	Rao (18)	Male bovine	Genitalia	20-100 micra	10-75 micra
		Female bovine	1. Clitoris	28-74 "	21-52 "
			2. Vestibule	50-60 "	23-42 "
			3. Labia	39-98 "	32-42 "

Bohm et al. (5) observed that these bulbs were round, oval or pear-shaped, and the capsule was thin with numerous nuclei. One, two or even three medullated nerves lost their sheath on entering the capsule and divided into vericose branches which formed a network and ended in knobs.

Ham (12), described two types of Krause end bulbs. The first type was an encapsulated granular mass in which the nerve fiber terminated at the superior pole in a small knob. The second variety, found in the conjunctiva, was a bulb in which the afferent nerve fiber branched repeatedly and ended in several free enlarged terminations.

Maximow and Bloom (15), state that these endings had a structure similar to that of the corpuscles of Vater-Pacini, but were smaller in size and simpler in construction.

Copenhaver and Johnson (10), described these end bulbs as the simplest of the encapsulated sensory nerve endings. The bulbs were spherical or oval in shape and consisted of a thin lamellated corpuscle of flattened connective tissue cells and fibers surrounding a central area called the inner bulb.

Winkelmann (30, 31, 32) described the ending of the mucocutaneous junction in man and cat. According to him various scientists gave different names to this structure such as the Krause end bulb, the genital body, the end capseln, the Dogiel body or the so-called end bulb of primates. He preferred to call this structure the mucocutaneous nerve ending for he thought all the above mentioned structures had the same basic morphological pattern and were located in the dermis of the skin at the mucocutaneous junction.

Winkelmann (30, 31) described that the mucocutaneous end organ was composed of loops of non-myelinated nerve fibers rolled on one another into spherical or oval masses resembling an irregularly wound ball of yarn. The

individual fibers maintained their integrity and gave of branches which did not anastamose with other fibers. From two to six myelinated fibers entered the end organ and gave off secondary branches. A nerve fiber after entering the end organ, divided and then left the first organ to enter and supply other end organs. As many as four end organs were observed to have a common parent innervation.

A specialized connective tissue capsule was absent and there were no special morphologic features of the cells in relation to the end organs. No constrictions or surface characteristics of structural importance were seen.

These end organs averaged 0.05 mm. in diameter. The largest reached a size of 0.1 mm. Their long dimensions were observed to be about twice their thickness so no estimation of size was recorded for it indicated an approximate figure. These endings were located chiefly in the subpapillary layers of the dermis. In the prepuce, eyelid, and lip, the end organs were mostly seen in close relation to and within the papillae.

These end organs were found in the mucocutaneous regions of human tissue, In his study those included were the glans penis, clitoris, prepuce, hermophroditic genital organs, lip, tongue, eyelid, and perineal region. The organs were not found in the haired skin, true mucous membranes, or distal regions of the glabrous skin.

Winkelmann (30, 32) stated that the mucocutaneous end organs in the cat were found in all regions of transitions from haired skin to mucous membranes. They were found in the lip, conjunctiva, perineal skin, palate, cheek, and the tip of the tongue. This sensory end organ was a long sepentine-like body with a heavy capsule. The myelinated fiber within the organ was convoluted.

The contents of the capsule appeared to be coiled on itself many times. It was shown that the end organ was supplied by a large myelinated nerve and more than one end organ was innervated by divisions of one large nerve trunk, thus producing clusters of end organs.

In the lip the end organs were found in comparatively dense concentration. In the perineal region end organs were relatively sparce being confined to the immediate zone of transition between hairy and non-hairy skin. They were also found to be less dense in the buccal mucous membranes. They were found in the tip and on the sides of the tongue but were not present in the papillary structure of the major portion of the tongue surface. The organs were sparce in the palate. Several were seen in the mucous membrane of the cheek. The end organs were numerous in the genital regions of both the male and female, but were confined principally to the zone of transition from skin to mucous membrane. None were found beneath the vaginal mucous membrane.

The mucocutaneous end organs were found to be the only specialized end organs in the papillary dermis of the cat's paw. A vertical section of the cat digit disclosed the end organ within the papillary structure and they were seen in almost every papilla.

The transitional zones between haired skin and true mucous membranes possessed a common sensory end organs. The basic structure of these end organs in the oral, anal, and genital zones was the same. The regions were also similar in their lack of hair follicles and their prominent papillae and rete ridges.

A survey of the literature revealed that the corpuscles of Vater-Pacini were oval or rounded bodies. Studies of Winkelmann (30) showed that they were slightly bent or arcuate. The capsule attained its greatest thickness

in these endings according to Maximow and Bloom (15). The capsule was composed of concentric lamellae which contained nuclei and were held apart by body fluid, Winkelmann (30). Schwarz, as quoted by Winkelmann (30), had shown that the fibers were neither collagenous or reticular in nature but they were glial fibers. A central canal surrounded the nerve fiber and was termed 'Innenkolben' by earlier authors.

Nerve fibers which entered these bodies were myelinated up to the Vater-Pacini body and lost their myelin sheath at the point where they entered the stalk of the body. The size of the corpuscle varied from 0.21 by 0.3 to 0.89 by 0.6 mm., Winkelmann (29). Trautman and Fiebiger (24) stated that they were large, 2.0 mm. and were present in the peritoneum and subcutaneous tissue, around joints, on the sympathetic trunks, in the mesentery and pancreas of the cat. They also were found in the parathyroids, the penis, clitoris, muscle sheaths, planum nasale and corium of hoofs and claws, and in the foot pads of carnivores. They also were located near the coccygeal artery of long tailed mammals and the glomus coccygeum of man, in the vicinity of the thoracic aorta and its large branches, in the follicles of tactile hairs. Winkelmann (33) found the Vater-Pacini corpuscles in the cat's paw, the genital region and the perineal region of the skin. They were not found elsewhere except along the tendons and the mesentery. At the base of each digit along the flexor tendon was an accessible Vater-Pacini corpuscle which was used for experimental purposes. Maximow and Bloom (15), state that these nerve endings ranging from 1.0 to 4.0 mm. in length and 2.0 mm. in width, were located in the deeper layers of the skin, under mucous membranes, in loose connective tissue in general.

Piersol (17), described the Vater-Pacini corpuscles as elliptical bodies,

2.0 to 3.0 mm. by 1.0 to 1.5 mm. They occurred along the nerves supplying the skin, especially the hand, foot and external genitalia. The corpuscle was described as consisting of 25 to 50 concentric connective tissue lamellae. The number of lamellae indicated by Trautman and Fiebiger (24), varied from 20 to 60. Each lamella consisted of an outer transverse and an inner longitudinal layer of fibers lined by a single layer of endothelial cells. The lamellae which surrounded the inner bulb were thinner and more compact than those of the periphery. The myelinated fiber coursed up the intracapsular ligament along which the lamellae were united and lost its medullary sheath where it gained entrance into the inner bulb. The free axis cylinder terminated in a knob-like structure, Piersol (17).

Rao (18) described the Pacinian corpuscles as being located in the deeper layers of the connective tissue of the external genitalia and similar in configuration to those found elsewhere. Winkelmann (33), described the Pacinian corpuscles of the skin of cat to be of the same histological structure as compared to that of man.

The sensory nerve endings have been classified in a variety of ways by different scientists (vide Tables 3, 4 and 5).

With constant increase in the use of silver stains for the demonstration of nervous tissue elements the classical methods of Bielschowsky and Cajal had become the standard neurological techniques for material done in bulk, Robers (19). The study of Kernohan (13) was the earliest regarding the adaptation of the silver impregnation method of Bielschowsky for material embedded in paraffin or celloidin.

Rogers (19) developed many types of silver stains for differentiating between nervous and connective tissue elements. Four methods were described

Table 3. Classification of sensory endings after Ruffini as quoted by Winkelmann (30).

1. Intraepidermal endings.
   - a. Network of Langerhans.
   - b. Hederiform endings.
   - c. Free nerve terminals.
2. Papillary layers.
   - a. Meissner's corpuscles.
   - b. Papillary floccules or tufts.
   - c. Free nerves.
   - d. Golgi-Mazzoni bodies (Dogiel).
3. Subpapillary layers.
   - a. Non-myelinated subpapillary network.
   - b. Monolobular corpuscles of Meissner.
   - c. Terminaisons arboriformis (Dogiel).
   - d. Golgi-Mazzoni bodies (Dogiel).
4. Reticular layer.
   - a. No endings except a small Ruffini-type described by Dogiel.
5. Subcutaneous tissue.
   - a. Corpuscles of Vater-Pacini.
   - b. Golgi-Mazzoni bodies.
   - c. Ruffini Bodies.

Table 4. Classification of sensory endings after Pinkus as quoted by Winkelmann (30).

1. Epidermal endings.
   a. Free nerve endings.
   b. Merkel tactile cells.
2. Hair follicle endings.
3. Lamellated or capsular end organs.
   a. Vater-Pacini corpuscles.
   b. Herbst corpuscles.
   c. Krause's end bulbs.
   d. Genital corpuscles.
   e. Golgi-Mazzoni bodies.
   f. Ruffini bodies.
4. Complex Cellular organs.
   a. Merkel tactile cells.
   b. Meissner's corpuscles.
   c. Dogiel bodies.

Table 5. Classification of dermal nerve endings in human skin after Winkelmann (30).

1. Hairy skin.		Nerve networks. Papillary nerves.	Hair follicle endings.
2. Glabrous skin.			
a.	General.	Nerve networks. Papillary nerves.	Complex papillary nerves
b.	Extremity	Nerve networks. Papillary nerves.	Meissner's corpuscles. Hederiform endings. Pacinian corpuscles.
c.	Mucocutaneous Junction	Nerve networks. Papillary nerves.	Complex papillary nerve. Mucocutaneous end organ. Meissner's type endings. Pacinian corpuscles.
d.	Mucous membranes	Nerve networks.	—

in detail which gave very good results. If it was desirable to stain the connective tissue elements a protoplasmic counter stain was recommended. He used 10 to 20 percent formol or Bouin's picro-aceto-formol as a fixative for seven days or longer.

Foley et al. (11) stated that the objective in the preparation of peripheral nerves for quantitative analysis was a complete staining and the definition of the smallest unmyelinated fibers. He recommended the use of various modified aqueous solutions of potassium dichromate which improved the fixation of the tissue and the staining qualities.

Bodian (2), described a simple and a reliable reduced silver method for staining of mounted paraffin sections of the central and peripheral nervous systems. This method gave uniform, sharp, and specific staining of nerve elements, including myelinated and unmyelinated fibers, neurofibrillae and the end feet. Again in 1937, Bodian (3) described the use of proper fixatives preceding impregnation with activated protargol. By this it was possible to stain selectively many diverse elements of nervous tissues. He recommended the use of formol-trichloracetic acid-alcohol as a fixative for nerve endings.

Winkelmann (28), developed the silver urea method for frozen sections but he discarded it in favor of an ammoniacal silver method in which he used 20 percent silver nitrate solution, 50 percent formol, 30 percent urea, and ammoniacal silver. This solution consisted of 1 drop of concentrated ammonia to 3 drops of 30 percent silver nitrate, prepared just before use, Winkelman (30). He claims this method which consumed only about 15 to 18 minutes, to be the shortest of the silver impregnation methods. Using this method it was possible to make the nerves stand out clearly.

RESULTS AND DISCUSSION

Bodian (3) described the procedure for fixing tissues for the study of peripheral sensory nerve endings. By fixation with alcohol, with formol trichlor acetic acid added, peripheral nerve endings stained brilliantly. For this study the tissue specimens were fixed in formol-trichloracetic acid-alcohol. According to this technique, after toning with gold chloride the sections were to be placed in a two percent solution of oxalic acid for five to ten minutes. Rao (18), observed that this solution turned the sections almost black in five minutes. He found that ten seconds in oxalic acid gave good results.

It was observed in this study that the solution of gold chloride gave varying results. In some instances it completely decolorized the sections and in other cases the sections turned uniformly grey. Treatment with 2 percent solution of oxalic acid was avoided in all those cases where the sections turned grey with previous treatment in gold chloride solution, for they turned black with oxalic acid in about fifteen seconds. However treatment in oxalic acid solution was carried on for one-half minute in cases where the sections were decolorized with gold chloride solution.

Bodian (3), recommended counterstaining with eosin, hematoxylin and eosin or Mallory's stain. This step was completely avoided in this study as the nerve endings and the background appeared less sharply defined when the method was attempted. A few sections from each of the tissue specimens were stained with one percent analine blue. When analine blue was used the background stained less intensely and the nervous elements were sharply defined.

Four types of encapsulated nerve endings namely Meissner's corpuscles, Krause end bulbs, mucocutaneous end organs and Pacinian corpuscles were

isolated. The structure of these end organs was basically similar to bodies found in humans in most cases.

Meissner's Corpuscles

Rao (18), described the presence of slight modifications of these receptors in the papillae of the genital epithelium of the bovine. He also noted that the typical horizontal arrangement of the tactile cells was absent, though the axon took a spiral turn.

In this study similar structures were noted in the dermal papillae of the planum nasale and the digital pads of cats and dogs. They were however not the only corpuscles present in the dermal papillae. Unencapsulated nerve endings were also found. Weddell et al. (27) have shown that these unencapsulated nerve endings occurred throughout the dermis from the stratum germinativum to the subcutaneous tissues. These unencapsulated nerve endings were formed of a fine network of naked axoplasmic filaments which mingled with one another and were given off at various levels by ensheated stem fibers.

The Meissner's corpuscles contained round or oval cells placed irregularly one over the other. The nuclei were round and located in the center of the cells. The corpuscle was covered externally by a thin connective tissue capsule which contained small irregular cells. Two to three myelinated nerve fibers entered the corpuscle. These fibers lost their myelin sheaths soon after they entered the corpuscle. The fibers terminated by branching into small naked filaments which ended in relation to the central round or oval cells.

Cauna (7) described the Meissner's corpuscles as the tactile corpuscles found in the hairless portions of the skin. They were well developed in the

human skin.

Meissner's corpuscles were the only organized encapsulated nerve endings in the regions of the digital pads. No other encapsulated sensory nerve endings were discernible in these regions.

Krause End Bulbs

These end bulbs were oval encapsulated bodies. They were made up of a capsule, an inner bulb and the axis cylinder. The capsule was made up of two to three layers of concentrically running connective tissue lamellae which contained extremely small fusiform cells. These cells presented bulgings in the regions where the nuclei were situated. The inner bulb surrounded the axis cylinder and was concentrically striated. No cells were found in any portion of the inner bulb. A myelinated nerve fiber entered the corpuscle and lost the myelin sheath at the point of entrance. The naked axis cylinder passed through the center of the inner bulb and terminated at the farther end in a small swelling. These observations were in close approximation to the descriptions of Trautman and Fiebiger (24).

The Krause end bulbs were located superficially in the stratum reticulare of the dermis and sometimes in close relation to or within the stratum papillare. They were only found in the dermis of the skin in the region of the planum nasale of the canine. The average dimensions of these bodies, as found in this study, were 60.0 by 37.0 micra. The dimensions of these bodies, as stated by various scientists, has been indicated in Table 2.

Mucocutaneous End Organs

These end organs were described by Winkelmann (30), in the skin of

humans and cats. They were found in all regions of transition between the haired skin and mucous membranes. These organs were described as having a different structure in humans and cats. The end organs of the human mucocutaneous zone were composed of loops of nonmyelinated nerve fibers rolled on one another into spiral or oval masses resembling an irregularly wound ball of yarn. The individual fibers maintained their integrity and gave off branches but did not anastamose with other fibers. From two to five fibers entered the end organ. These end organs averaged 0.05 mm. in diameter. The largest reached a size of 0.1 mm. He stated that their long dimensions were twice their thickness and hence any estimation of size was approximate. A specialized connective tissue capsule was stated to be absent. The cat end organ was a long serpentine-like body with a multilayered cellular capsule and convoluted myelinated nerve fiber.

In this study the mucocutaneous end organs were found only in the region of the planum nasale of cats and were not found in dogs. They were located in the superficial layers of the dermis and in contact with or within the papillary layer of the dermis.

These end organs were elongated tortuous structures. Their basic structure resembled that of the Krause end bulb with a few exceptions. These nerve endings were composed of a capsule and a myelinated nerve fiber. The capsule was thick, multi-layered and was formed by the orientation of the surrounding connective tissue of the area. Very small irregular cells were seen in the capsule. A myelinated nerve fiber entered the corpuscle and followed a tortuous course. An inner bulb was not found and the space between the myelinated nerve fiber and the capsule was structureless and hyaline-like.

The presence of mucocutaneous end organs and the absence of Krause end

bulbs in cats and the presence of Krause end bulbs and absence of mucocutaneous end organs in dogs is not quite understood. It can thus be deduced that Krause end bulbs of canines and mucocutaneous end organs of felines were probably concerned with similar functions.

Pacinian Corpuscles

Winkelmann (32) described these corpuscles in cats and found that they were entirely comparable to those found in other mammals. The components of these corpuscles were the stalk and the main body which was generally convoluted.

Rao (18), working on the sensory nerve endings in the genitalia of the bovine, reported that these lamellated corpuscles were the largest in size of the encapsulated sensory nerve endings that were studied.

In the present study these organs were located in the subcutaneous connective tissue and were surrounded by fat. They were usually oriented perpendicular to the surface of the epidermis. These end organs were seen in the planum nasale of both canines and felines but were not found in the digital pads of either species.

The Pacinian corpuscles were made up of a body and a stalk. The body was composed of the capsule, the inner bulb, and the axis cylinder. The capsule was made up of 25 to 30 concentrically running connective tissue lamellae which contained irregular cells. The outer layer of the capsule contained relatively few cells and was loosely arranged. The inner layers were thin, closely packed and contained a large number of cells. The inner bulb was colorless and formed the inner core of the corpuscle. The inner bulb contained the axis cylinder. The stalk was found at the point where the

myelinated nerve fiber entered the corpuscle. At the point of entrance the nerve fiber lost its myelin sheath and the naked axis cylinder passed all the way to the farther end of the corpuscle where it terminated in a small swelling. The size of the corpuscles did not differ much in both species and measured 0.7 by 0.2 mm. to 1.0 by 0.5 mm.

Rao (18) and Piersol (17) described an intracapsular ligament to which the lamellae were attached. No intracapsular ligament could be detected in this study.

CONCLUSIONS

From the observations made in this study it was seen that the sensory nerves innervating the skin passed through a cutaneous nerve plexus and became finer and finer towards their termination. The nerve plexus was arranged in two main layers. Arising from the superficial layers were nerve fibers which terminated either in encapsulated, unencapsulated or free nerve endings. The deep layers gave rise to the superficial layers and the Pacinian corpuscles. The results of this study confirmed the findings of Weddell (25).

Three types of encapsulated nerve endings were observed to originate from the superficial layers of the plexus. The Meissner's corpuscles in the papillae of the skin of planum nasale and digital pads of both the canine and the feline were of variable shapes, but in general they were elongated, nearly perpendicular to the surface of the epidermis and conformed to the descriptions of the Meissner's corpuscles of humans. Rao (18) made similar observations on the nerve endings in the genitalia of the bovine.

Krause end bulbs were seen in the superficial layers of the dermis in close relation to or within the dermal papillae. They were small, oval or

spindle-shaped with an inner bulb which was concentrically striated. The capsule was made up of two to three layers of concentric lamellae containing nucleated cells. They were only seen in the planum nasale of dogs and were not found in other parts included in this study. On the other hand mucocutaneous end organs were seen only in the dermis of the skin in the region of the planum nasale of cats and their location was comparable to that of Krause end bulbs in dogs. These mucocutaneous end organs were elongated tortuous structures with a thick capsule. This was formed by the orientation of the surrounding connective tissue fibers around the corpuscles. The myelinated fiber after entering the end organ followed a convoluted or a tortuous course, and the space between the nerve fiber and the capsule appeared colorless and hyaline-like.

In contrast to the previous three, the Pacinian corpuscles were deep seated in the subcutis and were surrounded by fat. They were oriented perpendicular to the surface of the epidermis. These nerve endings were seen in the planum nasale of both the canine and the feline but they were not observed in the digital pads of both species. The Pacinian corpuscles were oval elongated structures with the body of the corpuscle bent. This bending of the body led Winkelmann (30) to designate the shape as arcuate.

SUMMARY

1. The material for the study was obtained from the digital pads and skin from the region of the planum nasale of six canines and six felines all of mixed breeds. The tissues were fixed in formol-trichlor acetic acid-alcohol for seven days. Paraffin injections were cut at 20 micra, and stained by Bodian's Protargol method. Some sections from each of the tissue specimen

were counterstained with 1 percent solution of methylene blue.

2. Neurohistology of the skin in the regions of planum nasale and digital pads of the canine and the feline was studied. Four types of encapsulated nerve endings were found. Their structure and location were compared in both the species.

3. Krause end bulbs were seen in the planum nasale of dogs while mucocutaneous end organs were found in the planum nasale of cats.

4. Meissner's corpuscles were found in all the areas studied. They appeared to be the only type of encapsulated nerve endings found in the digital pads of both species.

5. Pacinian corpuscles were the rarest of all encapsulated nerve endings studied and they were found in the subcutis of the canine and feline in the region of the planum nasale.

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The author expresses his sincere gratitudes to his Major Professor Dr. D. M. Trotter, Head of the Department of Anatomy, for his advise and guidance. The author is also indebted to Dr. Harry C. Mussman for his timely suggestions and encouragement. In the last but not the least thanks are due to Mr. F. J. Hanna who has been responsible for the photomicrographs.

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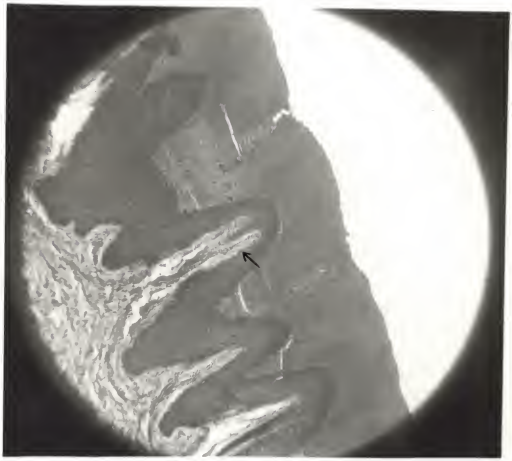
APPENDIX

EXPLANATION OF PLATE I

Section of the skin from the digital pad of the dog, X75. Protargol stain. Arrow points to the Meissner's corpuscle in the dermal papilla.

PLATE I



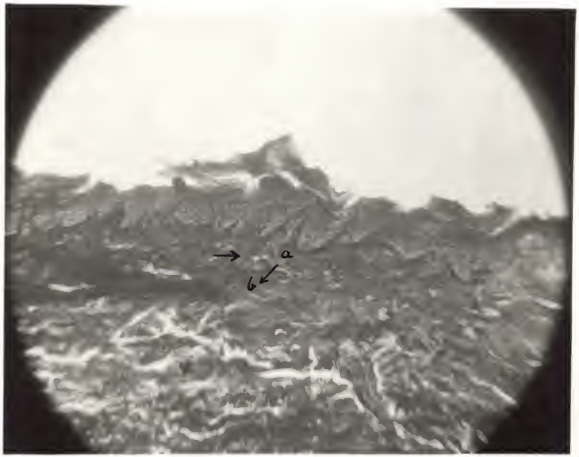
EXPLANATION OF PLATE II

Section of the skin from the planum nasale of the cat, X75. Protargol stain. Arrow points to the mucocutaneous end organ in the dermal papilla.

a. Capsule

b. Myelinated nerve fibre.

PLATE II



EXPLANATION OF PLATE III

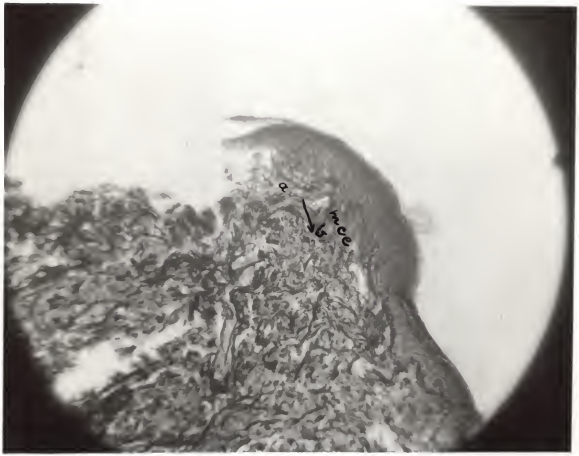
Section of the skin from the planum nasale of the cat, X75. Protargol stain.

mce. Mucocutaneous end organ in the superficial layers of the dermis.

a. Capsule.

b. Myelinated nerve fiber.

PLATE III



EXPLANATION OF PLATE IV

Camera lucida drawing of the mucocutaneous end organ from the superficial layers of the dermis of the skin in the region of the planum nasale of the cat.

a. Myelinated nerve fiber.

b. Capsule.

EXPLANATION OF PLATE V

Camera lucida drawing of the Krause end bulb from the superficial layers of the dermis of the skin in the region of the planum nasale of the dog.

a. Capsule.

b. Inner bulb.

c. Axis cylinder.

PLATE IV

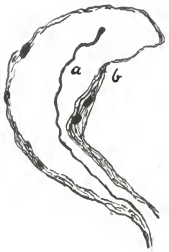
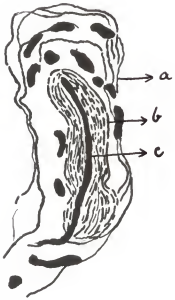
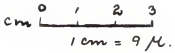


PLATE V





EXPLANATION TO PLATE VI

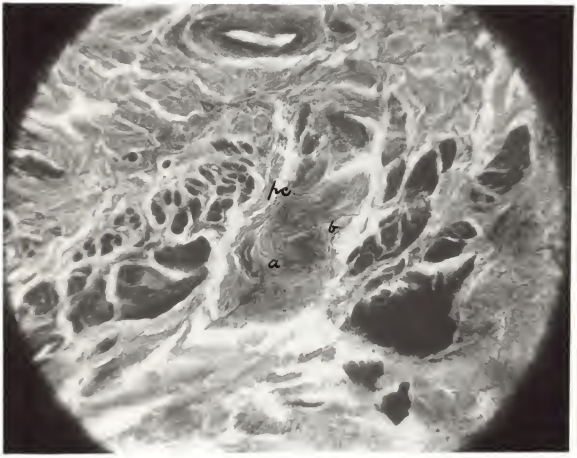
Section of the skin from the planum nasale of the cat, X75. Protargol stain.

pc. Pacinian corpuscle.

a. Stalk.

b. Body.

PLATE VI



EXPLANATION OF PLATE VII

Section of the skin from the planum nasale of the cat, X75. Protargol stain.

pc. Pacinian corpuscle.

a. Axis cylinder surrounded thin inner bulb, (lightly stained area)

b. Inner densely packed lamillae of the capsule.

c. Outer loosely arranged lamillae of the capsule.

PLATE VII

EXPLANATION OF PLATE VIII

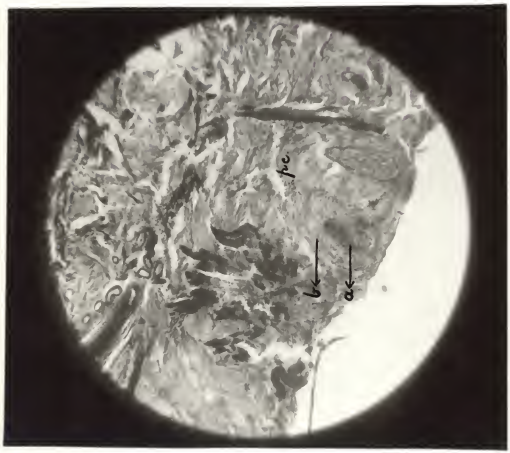
Section of the skin from the planum nasale of the dog, X75. Protargol stain.

pc. Pacinian corpuscle.

a. Axis cylinder surrounded by the inner bulb.

b. Capsule.

PLATE VIII



ENCAPSULATED NERVE ENDINGS IN THE DIGITAL PADS AND PLANUM NASALE OF DOGS AND CATS

by

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Much work has been done on the sensory nerve endings in the skin of humans. The available literature gives a generalization of the occurrence of these endings in the canine and the feline. This study was undertaken to observe the morphology and location of various types of encapsulated nerve endings in the digital pads and the skin from the region of the planum nasale of dogs and cats. The encapsulated nerve endings of both the species have been compared wherever possible.

The sensory nerves terminated in the skin either in encapsulated, unencapsulated or free nerve endings. The present study was restricted to the termination of the sensory nerves in the encapsulated receptor organs such as Meissner's corpuscles, the end bulbs of Krause, the mucocutaneous end organs, and the Pacinian corpuscles.

The material for the study was obtained from the digital pads and skin from the region of the planum nasale of six canines and six felines all of mixed breeds, within one-half hour after enthanasia. The tissue was fixed in formol-trichlor acetic acid-alcohol for seven days. Paraffin sections were cut at 20 micra, and were stained by Bodian's protargol method. Some sections from each of the tissue specimen were counterstained with 1 percent solution of methylene blue.

Four types of encapsulated nerve endings were recognized. The Meissner's corpuscles were situated in the papillae of the dermis of all the regions studied. They were elongated and varied widely in this shape and size. These were the only organized encapsulated end organs in the digital pads of canines and felines.

The end bulbs of Krause were found in the superficial layers of the dermis and sometimes in relation to or within the dermal papillae of the

planum nasale of dogs. These bodies were essentially made up of a capsule, which consisted of two to three layers of concentric lamellae, and the inner bulb which enclosed the axis cylinder. This inner bulb was concentrically striated.

Within the superficial layers of the dermis and often associated with the dermal papillae in the region of the planum nasale of the cats were the mucocutaneous end organs. These end organs for all practical purposes resembled the Krause end bulbs except for the absence of the inner bulb and, in contrast to the latter the end organ, was provided with a thick capsule. These end organs were serpentine-like bodies and were provided with a thick myelinated nerve fiber.

Examination of the subcutaneous connective tissue in the region of the planum nasale of both the canine and the feline revealed the presence of Pacinian corpuscles, which were the largest of the encapsulated nerve endings studied. They were however not found in the digital pads. These corpuscles were elongated oval in outline and oriented perpendicular to the surface of the epidermis.