THE INNERVATION OF THE INTEGUMENT OF CHIROPTERA, PP. 301 - 344

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INNERVATION OF THE INTEGUMENT OF CHIROPTERA

BY

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THE INNERVATION OF THE INTEGUMENT OF CHIROPTERA[1]

JAMES EDWARD ACKERT

From the Zoological Laboratory of the University of Illinois

TWENTY-ONE FIGURES (FOUR PLATES)

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INTRODUCTION

As is well known, the skin of bats is very sensitive to tactile stimulation. These animals in captivity give vigorous responses when various parts of their bodies and membranes are touched. Even eighteenth century investigators thought the integument of bats was especially adapted for the perception of delicate

[1] Contributions from the Zoological Laboratory of the University of Illinois, under the direction of Henry B. Ward, No. 29.

tactile stimuli, for Spallanzani and Cuvier observed that bats deprived of sight avoided small objects with accuracy. Cuvier found the wings to be supplied with an enormous number of nerves, and thought that during flight the blinded bat, on approaching the object, sets up air currents, which, reacting on the sensitive patagium and external ears, enable the animal to avoid the obstacle. That the sense of touch is more highly developed in bats than in other mammals was asserted by Schöbl ('71), who described 'Terminalkörperchen' at the bases of the hairs. Moreover, Redtel, two years later, maintained that it is possible for these animals to perceive the slightest difference of external air pressure upon their wings.

The extreme sensitiveness of the integument of these animals and the possibilities of modern technique seemed to justify a further search for sensory structures in their skin. Moreover, at the time this work was begun, no investigator had made an extensive study of the innervation of the skin of bats since Schöbl published in 1871 his account of the terminal corpuscles in the flying membrane.

The work has been carried on in the Zoological Laboratory of the University of Illinois under the direction of Prof. Frederic W. Carpenter, to whom I am indebted not only for his personal interest in the progress of the work, but also for his constant advice and helpful criticisms.

MATERIAL AND METHODS

The material for this investigation consisted of forty-one bats of which thirty-one were cave bats (Myotis lucifugus) from Indiana. The remainder, the common red bats (Myotis subulatus), were taken in the vicinity of Urbana, Illinois.

Most of the material was prepared by an intra vitam methylene blue method. The blood was washed out of the freshly etherized animal, and a 1 per cent solution of methylene blue in distilled water injected into the arterial system through the heart. After leaving the animal, with its vessels full of staining fluid, freely exposed to the air for oxidation, the fluid was washed out with

Ringer's solution, and small pieces of tissue fixed in a cold 8 per cent solution of ammonium molybdate in distilled water. The tissues were then dehydrated, cleared in xylol, and imbedded in paraffine. Sections of 20μ were thick enough to enable one to follow the nerve fibers some distance, and sufficiently thin to admit ample light. For checking results other methods of preparing material were employed. The killing and fixing fluids used for this purpose were corrosive sublimate and acetic acid, Zenker's fluid, ammoniacal alcohol, and 10 per cent formol. The stains used included silver nitrate (Cajal method for nerve fibrils), carmalum as a counter stain for methylene blue, Mallory's connective tissue stain, Heidenhain's iron hematoxylin, Hanson's hematoxylin and orange G, and Delafield's hematoxylin and eosin, the last of which proved the most satisfactory for general use.

OBSERVATIONS AND DISCUSSION

GENERAL STRUCTURE OF THE INTEGUMENT

1. *Integument of the body*

The skin of the body of bats is covered with hair which, as Allen ('93) has found, varies in different regions in texture and amount. In general, the crown of the head, the neck, the sides of the under surface of the body, the rump and the pubis have a thick pelage, while the distal portions of the ears, the soles of the feet, the mammae and the external genitalia are almost naked. The snout is scantily clothed, but shows a limited number of vibrissae which arise from wart-like structures.

In different regions of the body the skin varies greatly in thickness. The integument of the face is the deepest; that of other parts of the body diminishes in depth gradually in the following order: palmar region, plantar region, rump, ventral thoracic region, crown, and dorsal thoracic region.

As a rule, some difficulty is experienced in distinguishing all the layers commonly found in the human integument. In the epidermis the Malpighian or deeper stratum can be readily made out. Its deepest layer is made up of subcolumnar cells.

The intermediate layer of polygonal cells is for the most part absent, though in places (e.g., the face) it appears as a single sheet of isolated, more or less flattened cells, whose nuclei are somewhat reduced in size (fig. 1). Numerous pigment granules are present in this layer (fig. 1, *pg*).

The stratum corneum is thickest in the palmar and plantar regions. It is made up of several layers of cornified epithelium, the outer ones of which are usually in the form of loose scales. The deeper layers are more compact, and appear to consist of flat, enucleate cells. In certain regions of the body (lining of the mouth, lumbar region) these layers resemble to some extent the stratum lucidum of the human skin, but the presence of this stratum can be made out definitely only in the palmar and plantar regions (fig. 2, *sl*).

The surface of the epidermis is frequently interrupted by hairs, and also by the openings of ordinary sudoriparous and of modified sweat glands as Diem ('07), Porta ('10) and others have shown. The ordinary sweat glands and the modified sweat glands may open into the hair follicle, or independently on the surface. The distribution of skin glands over the body is very variable. Though not numerous in the region of the rump, sweat glands are, however, present. This is in accord with Diem's results, but opposed to those of Hoffman ('98). The writer was unable to find sweat glands in the sole of the foot, and agrees with Toldt ('07) that these glands do not occur in the ball of the thumb. Toldt found numerous glands in the 'Säugescheibe,' and also large groups of glands in the region of the neck and of the external genitalia. The upper lip is more abundantly supplied with skin glands than any other part of the body.

As is frequently the case, the superficial layer of the corium, the stratum papillare, is raised into ridges and papillae which project into the epidermis. These are most marked in the upper lip, where simple and compound papillae are present. The interlacing strands of connective tissue and the reticulum of elastic fibers which together form the ground work of the corium are comparatively fine and closely packed, thus causing this layer to be somewhat dense. Mallory's connective tissue stain shows that the general direction of these strands and fibers is parallel with that of the stratum Malpighii. While it is not possible to determine a boundary between the stratum papillare and the stratum reticulare, yet the deeper connective tissue bundles of the latter are obviously more loosely interwoven than those of the superficial layer of the corium. As in other mammals, the corium contains blood vessels, hair follicles, sebaceous glands, sudoriparous glands, striated and smooth muscle fibers, nerve trunks, medullated and non-medullated nerve fibers, tactile corpuscles, and nerve endings. The last three structures mentioned will be described in detail later.

As has been noted, the upper lip of the bat is richly supplied with skin glands. One type of these, the modified sweat gland, differs somewhat from the typical sweat gland, so a description of its structure may not be out of place here. Compared with a hair follicle, this gland is enormous in size. It consists of a long, uncoiled secreting portion with an extended funnel-shaped duct. The secretory portion is lined by a single layer of columnar cells with finely granular protoplasm and round or oval nuclei (fig. 3, *cc*). Leydig, Schöbl and Sabussow ('10) have called attention to the fact that these large modified sweat glands (in the flying and interfemoral membranes) have a coating of smooth muscle fibers, which, by their longitudinal course, cause a slight spiral striping of the gland. This coating of muscle fibers (fig. 3, *mf*) lies between the layer of columnar cells and an external covering or basement membrane (fig. 3, *bm*). The latter is homogeneous and without nuclei. The duct of the gland is lined throughout by short, somewhat irregularly cubical cells, arranged in a single layer, and surrounded by a delicate basement membrane. Not infrequently secretion products are found in the lumina of the glands. The products are more or less similar in appearance to what Wimpfheimer ('07) terms degeneration products ('detritus') found in uncoiled sweat glands in young moles.

It is worthy of remark that pigment cells occur in the corium both of the body integument and of the flying and interfemoral membranes (fig. 2, *pc*). In the corium of the integument they