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The Innervation of the Adrenal Cortex*

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Since FUSARI (1891) and DOGIEL (1894) made broad surveys on the innervation of the adrenal gland of mammals including man, the manner and extent of the innervation of the mammalian adrenal gland has been subjected to many investigators. For all the results of these works, however, many questions on this subject remain unsolved, and conflicting views have been put forward particularly on the presence of a parenchymal innervation of the cortex. Some investigators (FUSARI 1891, DOGIEL 1894, RENNER 1914, ALPERT 1931, PINES and NAROWTSCHATOWA 1931, STÖHR 1935, WILLARD 1936, DENBER 1944, KISS 1951, LEVER 1953, SARTER 1954, IWAKI 1955, and MIKHAIL 1961) maintained the presence of the nerves supplying the cortex, although their interpretations varied. On the contrary, other investigators (HOSHI 1926, KURA 1927, HOLLINSHEAD 1936, SWINYARD 1937, BENNET 1940, MACFARLAND and DAVENPORT 1941, EVANS 1947, SATO 1952, and WILKINS 1961) denied it, though some of them recognized the innervation of the blood vessels in the cortex. Generally they recognized nerve fibers running in the cortex toward the medulla, but they considered them as destined for the medulla or blood vessels in the cortex.

The adrenal glands of nonmammalian vertebrates do not differentiate into two portions, but the cortical tissue (interrenal tissue) and the chromaffin tissue are intermingled in varying degrees in the form of cell cords. The manner and extent of the innervation of the adrenal gland in these species, therefore, has been at issue in reference to that of the mammalian gland. Concerning the innervation of the adrenal cortex in nonmammalian vertebrates, YOUNG (1933) could find no nerves in the adrenal cortices of selachians except those to blood vessels. KOLOSSOW (1930) found very few nerves in the adrenal cortex of the turtle, though he attributed it to the presence of lipids in the tissue. In birds, GIACOMINI (1897) and KURA (1927) could find only very few nerve fibers in the cortex. HIRT (1930) alone observed no difference in the relationship of the nerves to the chromaffin and cortical cells of the frog adrenal gland. As far as these results concerned, the claim of FUSARI and others may appear to be not supported by the results obtained hitherto in regard to the adrenal glands of nonmammalian vertebrates. At the present, however, these results do not seem to be sufficient to draw any conclusion concerning this problem.

In the present paper, the authors have reinvestigated the distribution and termination of nerves in the mammalian and avian adrenal cortices, especially in its comparative aspects.

* Dedicated to the memory of the late Prof. Masaji SEKI.

Materials and Methods

The adrenal glands of monkeys (*Macaca irus*), dogs, rabbits and fowls were examined. The glands were removed from normal adult animals under nembutal anaesthesia, cut to pieces and fixed with 10% neutral formalin. Frozen sections were treated with the Bielschowsky silver-impregnation method modified by SCHEFTHALER and MAYET (1953). Besides, the Champy-Coujard technique was once employed, but the good results were only obtained in the connective tissue capsule of the gland and the zona glomerulosa.

Results

Innervation of the capsule

The afferent innervation of arteries which entered the adrenal gland was revealed. Fig. 1 shows an example in the rabbit. Together with sympathetic nerve

Fig. 1. An afferent nerve fiber (*nf*), and its ramifications (arrows) which run around the wall of an artery entering the capsule. *tb* Terminal branches of the afferent fiber, *sb* sympathetic neurofibrillar bundles. Rabbit.

fibers, a thicker nerve fiber and its branches ran along the wall of an artery which was entering the capsule of the gland. This terminal fibers branching from them coursed around the arterial wall.

A relatively large sympathetic ganglion was observed closely attached to the connective tissue capsule of the monkey adrenal gland. The ganglion cells were large and mostly multipolar, though bipolar cells were occasionally observed. The ganglion resembled those which some investigators (PINES and NAROWTSCHATOWA 1931, HOLINSHEAD 1936, and TEITELBAUM 1942) found in the cat adrenal gland, and TEITELBAUM regarded it as a displaced portion of the coeliac ganglion. In the connective

tissue of the capsule sympathetic ganglion cells were sometimes observed in very small groups of two or three cells.

In monkeys, nerve bundles of myelinated nerve fibers made simple plexuses in the capsule, while unmyelinated fibers formed fine plexuses including spread networks, throughout the subcapsular region.

The juxtacapsular ganglion was found also in the gland of the dog. It was much smaller than that found in the monkey, and it contained twenty to thirty cells. A nerve bundle of preganglionic fibers entered the ganglion and the fibers were distributed to the ganglion cells. Fine postganglionic fibers from the cells formed a bundle which entered the capsule.

The abundance of nervous elements in the capsule marked the adrenal gland of the dog, as it has been previously showed by DE CARO (1953). As nerve bundles of myelinated thick fibers reached the capsule, they ramified and anastomosed, and there were often formed large nerve plexuses. Arising from the constituent bundles of the plexuses, many club-shaped endings terminated singly or in small groups in the connective tissue (Fig. 2, a and b). In addition to them, there was another type of the afferent terminal formation in the connective tissue, that is, neurofibrillar sensory terminal plates which were also derived from nerve bundles

Fig. 2. Afferent terminal formations (arrows) in the capsule.

a and **b.** Club-shaped endings terminating in the connective tissue. **c:** Neurofibrillar terminal plates. **d.** A gromerular terminal formation in the wall of an artery. Scale marks indicate 20μ . Dog.

belonging to the capsular plexus (Fig. 2, c). Besides, sensory terminations were often observed in the walls of blood vessels in the capsule. Fig. 2, d shows one of these sensory terminations. A rather thick terminal fiber ended in a glomerular terminal formation without the capsule. Sensory terminations in the walls of blood vessels were described by DE CARO in the dog.

As mentioned above concerning the monkey adrenal gland, small bundles of unmyelinated nerve fibers formed plexuses in the subcapsular region of the dog adrenal gland, too.

It must be here noted that the above-mentioned nerve bundles of myelinated fibers were usually accompanied with many unmyelinated fibers. The unmyelinated fibers were impregnated much more lightly than black-impregnated myelinated nerve fibers. Consequently they were easily overlooked when they were mixed in myelinated fibers. The above-mentioned large nerve plexuses of myelinated fibers, therefore, contained many unmyelinated fibers. In this regard, it is interesting that COUPLAND (1965) observed electronmicroscopically the predominance of unmyelinated fibers over myelinated fibers in the greater splanchnic nerve and in the adrenal nerves in the rat.

In the same way, nerve bundles in various sizes which entered the gland independently of the capsular plexus, often contained unmyelinated fibers in different ratios, although they appeared, at first sight, to consist only of black-impregnated myelinated fibers. Large nerve bundles which consisted of several myelinated fibers and numerous unmyelinated lightly impregnated fine fibers, were sometimes observed in the capsule or in the cortex.

The presence of sympathetic nerve cells or ganglia in the capsule was reported by some investigators in different species, especially cats and dogs. In the present study, there were often found sympathetic nerve cells in small groups or singly in the capsule of the dog adrenal gland. They were commonly multipolar, but occasionally unipolar nerve cells were recognized (Fig. 3, a). In addition to these sympathetic nerve cells, there were occasionally found nerve cells in which cytoplasm a rather large club-shaped ending of a thick fiber terminated (Fig. 3, b). In the human adrenal medulla, STÖHR (1935) found nerve cells in which cytoplasm one or more club-shaped endings were seen. He considered the endings as receptor

Fig. 3. Nerve cells scattered in the capsule. **a.** Sympathetic nerve cells (arrows). **b.** A nerve cell in which cytoplasm a rather large club-shaped ending (*e*) terminates. *n* Nucleus of the cell. Scale marks indicate 20 μ . Dog.

apparatus. The nerve cells concerned showed some resemblance to those STÖHR described.

The fine subcapsular plexus of unmyelinated fibers was also recognized in the rabbit adrenal gland, but the plexus of thick fibers was not confirmed. Small nerve cells scattered were found in the connective tissue of the capsule in the rabbit, too.

Innervation of the zona glomerulosa

Fine nerve fibers which were distributed to the zona glomerulosa branched from the subcapsular plexus, and passed into the cortex (Fig. 4). They ran between the glomerular arches toward the boundary between the glomerular and fascicular zones. Their branches surrounded

Fig. 4. Fine nerve fibers (*ff*) which are distributed to the cortical cells (*cc*) of the zona glomerulosa, branch from the subcapsular plexus (arrows). *nc* Small nerve cell enmeshed in the plexus. Monkey.

the nests of cortical cells, and came into connection with adjacent fibers, forming rather large or small plexuses on the cell nests (Fig. 5). These fine branches and their plexuses were mostly very fine. They can be regarded as the strands of the autonomic endformation. ALPERT (1931) claimed that the peri- and intracellular termination of nerve fibers in the individual cells, were observed in the zona glomerulosa. His claim, however, could not be supported by the present investigation.

Many unmyelinated nerve fibers passed through this zone and entered the zona fasciculata, but they did not seem to be in relation with the plexuses on the cell nests. On the other hand, fine nerve fibers branched off from the nerve plexuses in the innermost region

Fig. 5. Fine neuroplasmic strands (*ns*) and their bundles (*bs*) form a plexus (arrows) on the nests of cortical cells in the zona glomerulosa. Dog.

Fig. 6. Distribution of probably afferent nerve fibers in the zona glomerulosa. Branching from myelinated thicker fibers (*tf*) of the capsular plexus, black-impregnated thin or medium-sized single fibers (arrows) enter the cortex. *br* Nerve branch distributed to the nests of cortical cells in this zone, *ff* fine nerve fibers, *cc*: connective tissue of the capsule. The scale mark indicates 20μ . Monkey.

of the zona glomerulosa and ran into the zona fasciculata.

In addition to the distribution of these autonomic nerve fibers in this zone, the distribution of other, probably afferent, nerve fibers were recognized. Branching from myelinated thicker fibers of the capsular plexus, black-impregnated thin or medium-sized single fibers entered the cortex (Fig. 6). Most of these nerve fibers appeared to pass through this zone and entered the zona fasciculata, but it was sometimes confirmed that some of these fibers gave off branches in this zone. The branches were distributed to the nests of cortical cells. These thin fibers showed small varicosities on their course at brief intervals. Single medium-sized fibers were often seen in the cortex. They went right on toward the medulla. At least many of them may be regarded as preganglionic sympathetic fibers which were distributed to chromaffin cells. It is, however, improbable that the nerve fibers concerned which branched in the zona glomerulosa, are the preganglionic fibers. It may be, therefore, reasonably concluded that they are afferent fibers.

Innervation of the zona fasciculata

Fine autonomic nerve fibers which were distributed to the zona fasciculata reached the zone in some ways. Deriving from the subcapsular plexus, fine unmyelinated fibers passed into this zone as single fibers or bundles

Fig. 7. A large plexus of neurofibrillar bundles (arrows) in the zona fasciculata. Rabbit.

of different calibers, running through the zona glomerulosa. Bundles of similar fibers sometimes passed into this zone in company with bundles of myelinated thick or thicker fibers, left the bundles, and ran obliquely or perpendicularly to the cell columns. Besides, nerve fibers came into this zone, branching from the plexus of the zona glomerulosa, as previously stated.

In rabbits, there were found many large nerve plexuses of fine fibers, while so large nerve plexuses were not seen in monkeys and dogs (Fig. 7). These plexuses were formed by rather large bundles of neurofibrils, which ran obliquely or in parallel with the cell columns, giving off many branches. The branches coursed toward the zona reticularis, ramifying successively to become the finest strands (Fig. 8, a and b). In monkeys, there were best revealed the distribution of the fine strands of

Fig. 8. **a** and **b.** bundles (arrows) of neurofibrils running toward the zona reticularis ramify successively to become the finest nerve strands (*ns*). *sc*: Schwann cell. Rabbit.

the autonomic endformation. Generally small bundles of fine nerve strands ran inwardly along the cell columns and bifurcated successively. The interstitial cells of the autonomic nervous system were often seen at the bifurcation. Fine beaded neuroplasmic strands of the autonomic endformation ran inwardly either along the cell columns or between cortical cells of the columns, ramifying. Moreover, many strands ran obliquely or horizontally between cortical cells, and got intertwined or anastomosed with adjacent strands. Fine plexuses were, therefore, often seen on cortical cells (Fig. 9, a and b). Such plexuses were often found on cortical cells in sections cut transversely to the cell columns as well (Fig. 9, c).

In the preparations from rabbits, nerve fibers which probably represented afferent fibers were observed in the zona fasciculata. In this zone, for instance, there

Fig. 9. **a** and **b.** Fine nerve plexuses formed by fine strands (arrows) of the autonomic endformation around cortical cells (cc) in the zona fasciculata. *sc* Schwann cell. **c.** A fine plexus observed in the cross section of cell columns. Scale marks indicate 10 μ . Monkey.

were observed a nerve bundle consisting of thick and medium-sized fibers, which a few medium-sized fibers left and made a very small plexus just on the outside of the bundle. Several black-impregnated thin fibers branched off from this plexus in some directions (Fig. 10, a). Two of them coursed in the opposite direction, centrifugally,

Fig. 10. Probably afferent nerve fibers in the zona fasciculata. **a.** A few medium-sized (probably afferent) fibers leave a nerve bundle (*nb*) in the zona fasciculata and make a very small plexus (*pl*) just on the outside of the bundle. Several black-impregnated thin fibers (arrows) branch off from this plexus in some directions. **b.** A medium-sized nerve fiber (arrows) runs along a nerve bundle coursing toward the medulla, and bifurcates. One of the bifurcations (arrows) turns back in the opposite direction. The fiber is presumably distributed to a venule (*v*). Rabbit.

for a while, and were distributed in this zone. The others ran obliquely, and were distributed in the transitional area from the zona fasciculata to the zona reticularis. In another instance, a medium-sized fiber which ran along a nerve bundle of thick and fine fibers coursing toward the medulla, bifurcated in the middle of this zone. Then one of the bifurcations turned back in the opposite direction, and was distributed in this zone. In the latter case, this probably afferent nerve fiber appeared to be distributed to a venule (Fig. 10, b). In monkeys, black-impregnated thin fibers were seen to run along the cell columns singly or accompanied by fine autonomic nerve strands (Fig. 11, a). As previously stated with regard to the zona glomerulosa, they were probably afferent in nature. In dogs, in addition to beaded autonomic nerve fibers, there were recognized nerve fibers of another type between cortical cells. They might be afferent fibers (Fig. 11, b).

Fig. 11. Probably afferent nerve fibers in the zona fasciculata. **a.** A black-impregnated thin fiber (*nf*) running along the cell column accompanied by fine autonomic nerve strands (arrows). *v* varicosity, *tf* thick nerve fiber. Monkey. **b.** A nerve fiber (arrow) which may be considered afferent in nature, between cortical cells. *ns* autonomic nerve strand, *cc* cortical cell. Dog.

In the zona fasciculata, there were often found small veins which ran in parallel with the cell columns. These veins were accompanied by thin or fine nerve fibers, which probably supplied them (Fig. 12, a). In rabbits, numerous blood capillaries or small blood vessels were clearly seen in this zone, but few nerve fibers seemed to be in direct contact with these vessels continually or repeatedly (Fig. 12, b). Fine nerve strands running around cortical cells, came upon capillaries. Consequently such contacts of nerve strands with small blood vessels and capillaries were sometimes observed.

Scattered nerve cells were uncommonly observed in rabbits and monkeys.

Innervation of the zona reticularis

The zona reticularis was supplied by autonomic nerve fibers which either came down directly from the capsule, or were continued from the bundles supplying the zona fasciculata. In the former case, some nerve fibers reached this zone as neurofibrillar bundles of different calibers directly from the capsule with very little or no previous branching, and others passed into this zone accompanied by bundles of thick fibers, which they left in this zone and supplied it. This mode of distribution of the nerve fibers was the same as seen in the zona fasciculata. These nerve bundles supplying this zone spread over the zone horizontally or obliquely giving off many branches successively (Fig. 13, 14, 15). The autonomic endformation spread over the zone. Fine strands of the endformation accompanied by Schwann cell and the

Fig. 12. Nerve fibers probably supplying blood vessels in the fasciculata. **a.** A small vein accompanied by thin or fine nerve fibers (*nf*). **b.** Small blood vessels or capillaries which are probably supplied with a fine nerve fiber (arrows). Rabbit.

Fig. 13. Nerve bundles supplying the zona reticularis spread horizontally or obliquely over the zone, giving off many branches (arrows) successively. Rabbit.

Fig 14. The autonomic endformation in the zona reticularis. Fine strands (arrows) of the endformation accompanied by Schwann cells (*sc*) and the interstitial cells (*ic*) surround large and small groups of cortical cells. *tf* thick nerve fiber, *nb* nerve bundle of fine fibers including two medium-sized fibers. Rabbit.

Fig. 15. The autonomic endformation in the zona reticularis. Neurofibrillar strands (arrows) surround the cell groups singly or in bundles. Monkey.

interstitial cells, surrounded large and small groups of cortical cells.

In rabbits, probably afferent fibers were revealed. Black impregnated thin nerve fibers branched off from nerve bundles consisting of medium-sized and thicker fibers in this zone and in the boundary between the fascicular and reticular zones. Then these fibers branched and spread rather widely among cortical cells (Fig. 16). Besides, in the inner part of this zone, there were often specific nerve fibers which

Fig. 16. Afferent nerve fibers in the zona reticularis. The fibers (arrows) branch off from a nerve bundle (*nb*) consisting of medium-sized and thicker fibers, and spread among the cortical cells. Rabbit.

bore resemblance to those which SARTER (1954) previously observed in the rabbit (Fig. 17). Accompanied by many unmyelinated fine fibers, myelinated very thick fibers and their branches ran in this zone. The main branches, medium-sized fibers, showed often large varicosities and were often divided into either fibers of the same caliber or fine fibrillar strands, which often anastomosed with the main branches and formed rings. One may regard these fibers as afferent fibers, but as SARTER pointed out, they presented some similarity to nerve fibers which were characteristically seen in the adrenal medulla and the paraganglia.

In monkeys and dogs, bundles of fine autonomic nerve fibers were sometimes accompanied by medium-sized fibers. Their nature, however, could not be concluded.

In monkeys and rabbits, scattered nerve cells were occasionally observed (Fig. 18).

Innervation of the adrenal cortex of the fowl

Nerve bundles consisting of predominantly myelinated thick fibers came to sympathetic ganglia which were situated just inside the connective tissue capsule of the gland. These ganglia contained many well-developed multipolar sympathetic

Fig. 17. Specific nerve fibers found in the zona reticularis. Accompanied by many unmyelinated fine fibers (*ff*), a myelinated thick fiber (*tf*) and its branches (*br*) run in the zona reticularis. A main branch shows varicosities (*v*) and is divided into either fibers (*nf*) of the same caliber or fine fibrillar strands (*fs*), which anastomose (arrows) with the main branch and form rings. Rabbit.

Fig. 18. A scattered nerve cell found in the zona reticularis. *nc* Nucleus of the cell, *cc* cortical cell, *mc* medullary cell, Monkey.

ganglion cells. Deriving from these ganglia, nerve bundles of medium-sized and thin fibers entered the cords of chromaffin cells, after running around the parenchyma of the gland for a while. In addition to these bundles, many bundles consisting of medium-sized, thin, and fine nerve fibers penetrated into the gland independently of the ganglia, and were distributed in it.

Nerve bundles ran in the cords of chromaffin cells throughout the gland, ramifying successively. Generally these nerve bundles did not get out of the cords of chromaffin cells. However, individual nerve fibers, mostly thin fibers, were often recognized to run across cortical cords to other cords of chromaffin cells.

Small groups of nerve cells were occasionally present among chromaffin cells, though HOSHI (1926) claimed that no nerve cell was found in the parenchyma of the gland.

Fig. 19. a-c. Fine nerve strands (arrows) running between the cortical cells. *mc* medullary cell, Scale marks indicate 15μ , Fowl.

Nerve fibers in the cortical cords in the fowl adrenal gland were much fewer than those recognized in the mammalian adrenal cortex, but not a few nerve fibers

Fig. 20. Nerve fibers supplying blood vessels in the cortex. **a.** A fine nerve strand (arrows) supplying a small blood vessel (*bv*) in a cord of cortical cells. **b.** A venule between cortical cords appears to be innervated by a thin, probably afferent, nerve fiber (arrows). Fowl.

Fig. 21. A complicated afferent terminal formation in the cortical tissue. **a.** Branching from a nerve bundle in the chromaffin tissue, a single medium-sized fiber (*nf*) enters the cortical tissue, and terminates both in the plates (arrows) of reticulated neurofibrils and a club-shaped ending (*e*). *np* Nucleus of the satellite plasmodium, *bc* dislocated red blood cell, *cc* cortical cell. **b.** Drawing of Fig. 21, a. Fowl.

were present in the cortical tissue. Leaving nerve bundles in the cords of chromaffin cells, single thin or fine fibers entered the thin connective tissue stroma between cortical cords, and then penetrated into the nests of cortical cells. Fine nerve strands were recognized to run between these cells, sometimes ramifying (Fig. 19). Small blood vessels were supplied with fine nerve strands (Fig. 20, a). Larger blood vessels seen between cortical cords might be innervated by thin fibers which were supposed afferent in nature (Fig. 20, b). Besides, not a few thin fibers penetrated into cortical cords directly from nerve bundles in the cords of chromaffin cells. As previously stated, some of these fibers appeared to run across the cortical tissue, but the others seemed to supply it.

Probably afferent nerve terminations were sometimes observed in the cortical tissue. Branching from nerve bundles in the cords of chromaffin cells, single medium-sized fibers entered cortical cords, and most of these fibers terminated in the plates of reticulated neurofibrils. Fig. 21 shows the most complicated example of these terminal formations. The medium-sized fiber appeared to end both in a plate of reticulated neurofibrils in a complicated form, and in a club-shaped ending.

Discussion

There were very few investigations concerning the innervation of the avian adrenal cortex. GIACOMINI (1891) could find only few fine nerve fibers in the adrenal cortices of birds. HOSHI (1926) failed to find nerve fibers in the fowl adrenal cortex. KURA (1927) observed very few nerve fibers running around the cortical tissue in the pigeon. HOSHI concluded that the nerve fibers seen in the mammalian adrenal cortex were not distributed to the cortex itself, but to the medulla, because no nerve fiber failed to be found in his silver-impregnated preparations of the adrenal cortex of the fowl.

In the present investigation, however, considerable number of nerve fibers were recognized to supply the cortical tissue of the fowl adrenal gland. Some nerve fibers appeared to be distributed to the nests of cortical cells. Other fibers were recognized to supply the blood vessels in the cortical tissue. Besides, probable receptors of afferent nerve fibers were found among the cortical cells.

As for the mammalian adrenal cortex, the present study showed that the three zones of the adrenal cortex were richly innervated by efferent and afferent fibers. Some investigators maintained that nerve fibers observed in the cortex, ran to the medulla without supplying the cortex. The present investigation also revealed the presence of such nerve fibers or bundles in the cortex. It was, however, confirmed that many nerve bundles and fibers were distributed in all the zones of the cortex. ZECKWER (1935) suggested that the stimulation of the autonomic nervous system caused the vasodilation and vasoconstriction of adrenal small veins. The present study confirmed the innervation of these small blood vessels. Besides, it was recognized that many fine nerve fibers which terminated in the cortex, necessarily came upon blood capillaries in their course. From this fact, one may presume that the capillaries were innervated by these fibers. Judging from the mode of distribution, however, these nerve fibers appeared to be much more closely related with the cortical cells than the capillaries.

On the other hand, there is no reliable evidence to show that every capillary is

supplied with the nerve fiber. Recently GRIGOR'EVA (1962) has even stressed that the 'true' capillaries are not supplied with nerves, though other investigators oppose her view. Besides, it appears improbable that all the fine nerve fibers that made plexuses around the cortical cells, are distributed only to the blood vessels in the cortex, even if the innervation of blood capillaries is recognized. Therefore, the presence of nerve fibers for the cortical cells must be taken into consideration.

If the nerve fibers running around cortical cells made such pericellular networks as ALPERT (1931) described, it might be readily accepted that the cortical cells were supplied with these fibers. Actually this claim of ALPERT, however, is not supported by the present study. The figures of his paper seem to show that he mistook argentophil connective tissue fibers for nerve fibers, as it has been already pointed out by SWINYARD (1937) and others.

It seems that any positive evidence has been not yet obtained experimentally concerning the presence of the efferent nerve fibers for the cortical cells. After splanchnicectomy, SANTAMARIA-ARNÁIZ (1963) observed that the cortex of the denervated adrenal gland contained more birefringent substances than the intact adrenal cortex. He supposed, however, that it was caused by the vascular change following the denervation.

The existence of the secretory nerve in the glandular tissue, however, seems to be generally accepted in the salivary gland which has been well investigated physiologically with regard to the secretory nerve, though many conflicting views are presented concerning its functional rôle (BURGEN and EMMELIN 1961). Though nerves supplying the blood vessels, play a very important role in the secretion of saliva, the secretory nerve performs a specific function in the secretion.

As for the presence of the efferent fibers supplying the parenchymal cells of endocrine glands, HAGEN (1956) has recently recognized it histologically in the islet of Langerhans of the pancreas, BRETTSCHEIDER (1963), SHIODA (1963), and MAKITA et al. (1966) in the thyroid gland, and PETERS (1957), STACH (1963), SHIODA (1964), and SHIODA and NISHIDA (1966) on the interstitial cells of the testis. In these tissues, the blood capillaries were not accompanied with fine autonomic nerve strands, though they were sometimes recognized to traverse these capillaries as seen in the adrenal cortex.

In the adrenal cortex of the fowl, there were not found so many nerve fibers of probably efferent nature which seemed to be distributed to the cortical cells, but they were not so few as they could be set aside. In this regard, the investigations above referred to, suggest that the efferent nerve fibers supplying the parenchymal cells are not distributed to the individual cells, but to the cell groups. Besides, it has been concluded in the salivary gland that nerve fibers may stimulate secretory cells which are not in anatomical contact with them (BURGEN and EMMELIN 1961).

Taking all these considerations into account, it seems reasonable to conclude that the cortical cells of the adrenal cortex are supplied with efferent nerve fibers in the mammals as well as in the birds.

The presence of afferent nerve fibers in the adrenal cortex was previously claimed by KISS (1961) in the zona glomerulosa, and SARTER (1954) suggested it in the zona reticularis. The present investigation showed that nerve fibers of probably afferent nature were distributed in all the cortical zones. In the thyroid gland, the termina-

tion of afferent nerve fibers on the blood vessels and the follicles themselves has been recently claimed by some investigators (BRETTSCHEIDER 1963, SHIODA 1963, LASSMANN 1964, and MAKITA et al. 1966). The present study failed to reveal the details of the termination of these fibers, but it is highly probable that the blood vessels in the cortex are richly innervated by afferent nerve fibers.

Summary

1. The distribution and termination of nerve fibers in the mammalian and avian adrenal cortices was histologically investigated in sections treated with a modification of the Bielschowsky silver-impregnation method.

2. Juxtacapsular ganglia were found in the monkey and dog. In the capsule of the adrenal gland, nerve cells were observed singly or in small groups. Scattered nerve cells were occasionally found in the zona fasciculata and the zona reticularis, too.

3. In the capsule, many terminal formations of afferent nerve fibers were observed in the dog.

4. Fine strands of the autonomic endformation made plexuses around the nests of cortical cells in all the cortical zones.

5. Probably afferent nerve fibers were recognized to terminate in the cortical zones.

6. The blood vessels in the cortex were innervated by probably afferent as well as efferent nerve fibers.

7. In the adrenal gland of the fowl, fine nerve fibers were recognized to be distributed to the nests of cortical cells as well as to the blood vessels. Larger blood vessels were probably supplied with afferent fibers. Besides, complicated receptor formations were observed among the cortical cells.

副腎皮質の神経分布 (内容自抄)

1. 哺乳類 (サル, イヌ, ウサギ) と鳥類 (ニワトリ) の副腎皮質における神経線維の分布と終末について BIELSCHOWSKY の鍍銀法の変法を用いて, 組織学的に検索した.

2. サルおよびイヌで, 副腎被膜に接して神経節が見られた. また神経細胞は, 単独に, あるいは数個の群をなして副腎被膜中に見出されるが, これは, とくにイヌにおいて多数見られた. 神経細胞は, そのほか, 束状帯と網状帯においても, 時に見られた.

3. イヌの副腎被膜中には, 求心性神経線維の終末が, 多数見られた.

4. 副腎皮質の各帯において, 自律神経終末の微細な線維が, 皮質細胞群のまわりを囲み, あるいは細胞間を走って, 小神経叢を形成していた. 皮質細胞群は, 神経支配を受けていると考えられる.

5. おそらく求心性と考えられる神経線維が, 副腎皮質の各帯に分布するのが認められた.

6. 副腎皮質中に見られる小血管には, 自律神経線維の分布が見られたが, さらに, 求心性神経線維の分布も, 一部 認められた.

7. ニワトリの副腎においては, 皮質中にかなりの数の細い自律神経線維の走行が認め

られ、この一部は小血管に分布するが、他は皮質細胞群に分布するものと思われた。やや大きい血管は、求心性神経線維の分布を受けるように思われた。また、皮質細胞群には、やや複雑な求心性終末構造が認められた。

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