

A HISTOLOGICAL STUDY OF SENSORY NERVES IN THE URINARY ORGANS

by

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I INTRODUCTION

It is clinically accepted that abdominal pain arises frequently as a symptom of diseases of the urinary organs, e. g., acute nephritis, nephrolithiasis, ureterolithiasis, acute cystitis etc.

ZIMMERMANN, NEUMANN and many other investigators have already proved the existence of sensitivity in the urinary organs from the physiological standpoint. Recently, CH. KIMURA and Y. YOSHIKKE of our clinic have proved the sensitivity in the urinary organs of human beings and cats with their physiological experiments using electric and mechanical stimulation or Kimura's Acetylcholine method.

KUNTZ, KAWAKAMI, KUBO and others have maintained, from the physiological point of view, that the sensitivity of the urinary organs is mediated through the sympathetic, vagar and pelvic nerves, while LANGLEY, EDGEWORTH, RANSON and WHITE, from the histological standpoint, have confirmed that visceral afferent nerve fibers are certainly contained in these nerves.

Among the reports studying on the sensitivity of the urinary organs, few of them described the sensory nerve endings histologically.

In this histological study, sensory nerve endings were sought in the urinary organs, and then an experimental observation was attempted for the determination of the course of these sensory nerves.

II MATERIALS AND METHODS

The materials used in my study were the urinary organs of human beings and dogs. The author used only fresh specimens taken from the kidney, ureter and bladder which were resected operatively. After fixation for 3~4 weeks in 10%

neutral formol solution, the specimens were frozen, sliced in thickness of $35\sim40\mu$, fixed again in 10% neutral formol solution for more than 2~4 months, and then stained.

The axis-cylinder was stained with SETO's or SUZUKI's modification of BIELSCHOWSKY's silver impregnating method, while the myelin sheath was stained with EHRLICH's acid hematoxyline method.

For experimental observations, adult dogs were used as experimental animals. Operations were carried out under general anesthesia with the injection of isomylal-sodium, and thoracotomy was performed under positive pressure breathing.

Considering the results of various experiments performed by many investigators from the anatomical or physiological standpoint, it can be assumed that most of the afferent nerves of the urinary organs are derived from the thoracolumber, vagar and sacral nerves. According to J. N. LANGLEY, visceral afferent nerves have their cell-stations in the dorsal ganglia of the spinal cord; and NEUMANN and NITTA have proved that the afferent nerve fibers arise from the ventral roots of the spinal cord.

Therefore, the spinal nerves and the vagus were sectioned at various points in my study in order to determine the course of the afferent nerves. Operations were carried out on the dorsal and ventral roots of the spinal cord distal to spinal ganglia, and on the vagar nerve. Secondary degeneration of nerve fibers in the urinary organs was observed mainly by EHRLICH's method as well as by BIELSCHOWSKY-SUZUKI's method. Degenerated nerve fibers were sought for in the peripheral layer where autonomic nerves have already changed their neurons.

According to the results of many experiments performed by investigators of our clinic, peripheral nerves demonstrate the secondary degeneration 5~6 days after the section of the roots of the spinal cord. Considering these results, the urinary organs of dogs were extirpated 5~6 days after rhizotomy. But after vagotomy, a few degenerated nerve fibers were observed in the kidney which extirpated 7~8 days after operations.

Operations were performed as follows:

- 1) Section of the dorsal roots on both sides (Th. 3...Th. 4)
- 2) Section of the dorsal roots on both sides (Th. 5...Th. 6)
- 3) Section of the dorsal roots on both sides (Th. 7...Th. 9)
- 4) Section of the dorsal roots on both sides (Th. 10...Th. 12)
- 5) Section of the dorsal roots on both sides (Th. 13...L. 1)
- 6) Section of the dorsal roots on both sides (L. 2...L. 4)
- 7) Section of the dorsal roots on both sides (L. 5...L. 7)
- 8) Section of the dorsal roots on both sides (S. 1...S. 3)
- 9) Section of the dorsal roots on the right side (Th. 10...L. 4)
- 10) Section of the dorsal roots on the right side (S. 1...S. 3)
- 11) Section of the ventral roots on the right side (Th. 10...L. 4)
- 12) Section of the ventral roots on the right side (L. 5...L. 7)
- 13) Section of the ventral roots on the right side (S. 1...S. 3)

Next, vagotomies were performed as follows;

- 14) Cervical vagotomy on the right side at a point distal to the ganglion nodosum
- 15) Cervical vagotomy on the left side at a point distal to the ganglion nodosum
- 16) Bilateral vagotomy in the thorax

III MICROSCOPIC OBSERVATIONS OF THE URINARY ORGANS

- 1) Intrinsic nerves of the kidney of human beings and normal adult dogs

Many investigators have described that the myelinated nerve fibers which enter the renal parenchym from the hilum lose most of the myelin sheath. RENNER observed very few small sized myelinated nerve fibers in the renal parenchym.

According to the results of my experiments, myelinated nerve fibers are observed abundantly in the renal medulla, cortex, calyx and pelvis. But these nerves are fewer in the convoluted tubules of the renal medulla than in those of the cortex.

The myelinated nerve fibers, being accompanied by non-myelinated nerve bundles, enter the renal parenchym from the hilum with the renal blood vessels and are traced along the interlobular blood vessels to the vasa afferentia and vasa efferentia. (Fig. 1, 2 and 3). Myelinated nerve fibers are mostly small-sized, but a few medium-sized ($4-6\mu$ in diameter) and very few large-sized (more than 7μ in diameter) nerve fibers are observed in the renal hilum, calyx and capsule. (Fig. 4 and 5).

Observing the silver stained preparations, axis-cylinders show a similar distribution as myelinated nerve fibers; axis-cylinders enter the renal parenchym from the renal hilum and spread over the peripheral layer. In all portions the "Nervose Synzytium" (JABONERO) can be observed (Fig. 6 and 7). They never terminate in free endings, but their neurofibrils form a fine network. In the renal tissue, thick nerve fibers are found besides the autonomic nerve fibers mentioned above. These thick nerve fibers show the characteristic varicosities and they are easily distinguished from the fine networks of the autonomic nerve fibers. Therefore, it can be deduced that these thick nerve fibers are identical with the sensory nerves described by H. SETO. These thick nerve fibers terminate freely in the wall of the interlobular blood vessel (Fig. 8 and 9), or are traced around the BOWMANN'S capsule to the glomerulus (Fig. 10, 11 and 12). Neither a termination with complicated structure nor a nerve cell is observed in the renal parenchym.

- 2) Intrinsic nerves of the ureter of human beings and normal adult dogs.

Myelinated nerve fibers are accompanied with non-myelinated nerve bundles. They enter the muscular layer along the blood vessels and arborize in the submucous layer (Fig. 13 and 14). A few myelinated nerve fibers enter the muscular and submucous layer without accompanying the blood vessels. They are less in number in the upper portion of the ureter than in its lower portion. Myelinated nerves usually consist of small-sized fibers, besides a few medium sized, but no large-sized fibers. A few myelinated nerve fibers, though medium-sized in the subserous or muscular layer, becoming small sized in the submucous layer, terminate freely in the mucous layer.

In the preparations stained with the silver impregnation, the autonomic nerve fibers are found in the muscular and submucous layer as networks. Besides them,

however, thick nerve fibers are traced from the subserous to the muscular and submucous layers. They run accompanied with the autonomic nerve fibers or separately and show a wavy appearance in the peripheral layer. These thick nerve fibers with characteristic varicosities coincide morphologically with the sensory nerves in the lower portion of the ureter reported by SETO and YOKOYAMA.

The author found these arborized thick nerve fibers in the mucous layer in the upper portion of the ureter of the dog (Fig. 15) and simple free-ending thick nerve fibers in the mucous layer in the middle and the lower portion of the ureter of human beings and dogs (Fig. 16 and 17). The course of these fibers are identical with those of the myelinated nerve fibers.

Nerve cells are observed only in the muscular layer of the lower portion of the ureter of a dog (Fig. 18).

2') Intrinsic nerves of the ureter of human beings suffering from ureterolithiasis.

The course of the nerve fibers in the specimens taken from a patient suffering from ureterolithiasis is similar to those in the normal specimens, except that in the case of ureterolithiasis abnormally undulated nerve bundles appeared in the submucous and muscular layers (Fig. 19). Both the "Terminalreticulum" and thick nerve fibers are more abundant than in the normal specimens (Fig. 20). A few thick nerve fibers in the submucous layer of the pathologic specimens are sometimes broken or show ampule-shaped swellings in places (Fig. 21).

3) Intrinsic nerves of the urinary bladder of human beings and adult dogs.

In the normal urinary bladder of human beings and dogs, a considerable number of myelinated nerve fibers are found in all portions, especially numerous in the trigonum. Most of these myelinated nerve fibers are small in diameter (Fig. 22). But a few medium-sized fibers are found in the submucous layer and a small number of large-sized fibers is found in the muscular layer of the trigonum. Large bundles of myelinated nerve fibers and large nerve plexus are observed in the muscular tissue (Fig. 23 and 24). Most of the myelinated nerve fibers run through the muscular layer and enter the submucous and mucous layers. Some of them arborize in the submucous layer ending freely in the mucous layer without any relation to nerve cells in the muscular layer.

Observing the silver stained preparations, nerve fibers are found abundantly in all layers together with "Nervoese Synzytium" (JAEONERO) along the wall of small blood vessels in the submucous layer (Fig. 25). The "Nervoese Synzytium" in the urinary bladder shows a wavy appearance. This deformation of the "Nervoese Synzytium" may be an adaptation for the action of the bladder muscles.

Thick nerve fibers, which are considered myelinated, run through the muscular layer without any relation to nerve cells and terminate freely in the muscular, submucous and mucous layers (Fig. 26, 27, 28 and 29).

These terminations never show complicated structures.

IV EXPERIMENTAL DEGENERATION OF THE SENSORY INNERVATION OF THE URINARY ORGANS

Using adult dogs as experimental animals, operations were performed as follows:

Laminectomy was performed under general anesthesia with sodium isomytal. The spinal canal was opened, and the dorsal and ventral roots were separated carefully from each other and only the ventral or the dorsal roots were cut at a point distal to their ganglia on both sides or on one side. The urinary organs were mostly resected 5~6 days after rhizotomy. Vagus nerves were cut on one side in the neck distal to the ganglion nodosum or on both sides in the thorax under positive pressure breathing. Specimens were taken out more than 6~7 days after vagotomy, and stained with EHRLICH's hematoxyline method.

(1) Section of the dorsal roots on both sides (Th. 3...Th. 4)

No degenerated nerve fibers are found in the urinary organs.

(2) Section of the dorsal roots on both sides (Th. 5...Th. 6)

(3) Section of the dorsal roots on both sides (Th. 7...Th. 9)

In all cases, a few degenerated myelinated nerve fibers are found in nerve bundles in the renal hilum and around the interlobar blood vessels in the renal medulla (Fig. 30). The myelin sheaths of these degenerated nerves are stained unequally, broken in places and look like granules or oil drops. In the ureter and bladder, there were no degenerated nerve fibers.

(4) Section of the dorsal roots on both sides (Th. 10...Th. 12)

Many degenerated nerve fibers are found in the renal parenchym (Fig. 31). In the ureter, only in its upper portion, a few degenerated nerve fibers are observed in the subserous and submucous layers (Fig. 32 and 33). In other portions of the ureter and in the bladder, no degenerated nerve fibers are found. In the renal capsule a medium-sized degenerated nerve fiber is discovered (Fig. 34).

(5) Section of the dorsal roots on both sides (Th. 13...L. 1)

Most of the myelinated nerve fibers with different calibers of the nerve bundle running along the interlobar blood vessels in the kidney show degeneration (Fig. 35 and 36). Moreover, a few degenerated nerve fibers are observed along the interlobular blood vessels (Fig. 37). In the silver stained preparations, a few degenerated nerve fibers in nerve bundles are observed in the renal hilum (Fig. 38), but they do not appear in the more peripheral layer. In all portions of the ureter, many degenerated nerve fibers are found in the submucous and mucous layers (Fig. 39 and 40). In the bladder, only a few degenerated nerve fibers are found in the muscular layer.

(6) Section of the dorsal roots on both sides (L. 2...L. 4)

A few degenerated nerves are observed in the renal parenchym, in the lower portion of the ureter and in the mucous membrane of the bladder (Fig. 41 and 42). The number of degenerated nerve fibers in the bladder is fewer in the trigonum than in its lateral wall and fundus.

(7) Section of the dorsal roots on both sides (L. 5...L. 7)

No degenerated nerve fibers are found in the urinary organs.

(8) Section of the dorsal roots on both sides (S. 1...S. 3)

No degenerated nerve fibers are found in the kidney, but in all portions of the

ureter a few degenerated nerve fibers are found in the muscular and submucous layers (Fig. 43). In all portions of the bladder many degenerated myelinated nerve fibers are observed, and especially in the trigonum almost all of the myelinated nerve fibers in the submucous and mucous layers show degeneration (Fig. 44 and 45).

(9) Section of the dorsal roots on the right side (Th. 10...L. 4)

In the urinary organs of the right side many degenerated nerve fibers are found. In the kidney and the ureter of the left side, there are no degenerated nerve fibers. On the left side of the bladderwall a few degenerated nerves are observed, but the number is far less than those of the right side.

(10) Section of the dorsal roots on the right side (S. 1...S. 3)

In the ureter and the bladder of the right side degenerated nerve fibers are found in the submucous layer, but on the leftside ureter no degenerated nerve fibers are observable. On the lefthalf of the bladder, however, some nerve fibers in the

The distribution of sensory nerves of the urinary organs from the viewpoint of secondary degenerations by the following sections of the nerve trunks

	Periods from section to extirpation	Kidney		Ureter		Bladder	
		sectioned side	opposite side	sectioned side	opposite side	Sectioned side	opposite side
bilat. post. rhiz. Th. 3 - Th. 4	5 days	—		—		—	
" " Th. 5 Th. 6	"	+		—		—	
" " Th. 7 Th. 9	"	+		—		—	
" " Th. 10 Th. 12	"	++		+		—	
" " Th. 13 L. 1	"	+++		++		+	
" " L. 2 - L. 4	"	+		+		++	
" " L. 5 L. 7	"	—		—		—	
" " S. 1 - S. 3	4.5 days	—		+		+++	
right post. rhiz. Th. 10 L. 4	5 days	+++	—	++	—	+	+
" " S. 1 - S. 3	4.5 days	—	—	+	—	+++	+
right ant. rhiz. Th. 10 L. 4	5 days	—	—	—	—	—	—
" " L. 5 L. 7	"	—	—	—	—	—	—
" " S. 1 - S. 3	"	—	—	—	—	++	+
(in the neck) Vagotomy	7-8 days	—	—	—	—	—	—
l. Vagotomy	"	—	—	—	—	—	—
(in the thorax) bilat. Vagotomy	"	+	—	—	—	—	—

muscular layer show degeneration (Fig. 46), but far less in number comparing with the right-half.

(11) Section of the ventral roots on the right side (Th. 10...L. 4)

(12) Section of the ventral roots on the right side (L. 5...L. 7)

In all cases, no degenerated nerve fibers are discovered in any portion of the urinary organs.

(13) Section of the ventral roots on the right side (S. 1...S. 3)

No degenerated nerve fibers are found in the kidney and ureter. But in the bladder, the degenerated nerve fibers are found in the submucous and mucous layers not only on the right half but also on the left half of the bladder (Fig. 47). The number of these degenerated nerve fibers is less than in case of posterior rhizotomy.

(14) Right vagotomy (in the neck distal to the ganglion nodosum)

(15) Left vagotomy (in the neck distal to the ganglion nodosum)

No degenerated nerve fibers are observed in both cases. (Observed 6~8 days after operation).

(16) Bilateral vagotomy.

Both the ventral and the dorsal branches of the vagus nerve are cut in the thorax and degenerated nerve fibers are sought for 6~8 days after operation. Degenerated nerve fibers are observed only in the renal parenchym on the right side (Fig. 48), and no degenerated nerve fibers are observed in the rest of the urinary organs.

(17) The results of the leftside rhizotomy vice versa.

V DISCUSSION

In regard to the peripheral structure of the autonomic nerves, BOEKE, STOEHR Jr., JABONERO and others have described many morphological studies. According to their opinions, the autonomic nerve fibers usually form a fine network in the periphery without terminating freely. STOEHR, SETO and others insist that the "Terminalreticulum" never degenerate, even if the preganglionic nerve fibers of the autonomic nerves are sectioned.

LANGLEY, SHEEHAN and other investigators determined physiologically that visceral afferent nerve fibers which pass through the sympathetic trunk have cell-stations in the dorsal root ganglia and reach the effector organs without changing their neurons on the way. LANGLEY demonstrated that these visceral afferent nerve fibers consist of myelinated nerve fibers.

When the spinal nerves are cut at a point distal to the dorsal root ganglia, only these visceral afferent nerves should, therefore, be degenerated throughout their course.

On the other hand, H. SETO has discovered free-ending thick nerves in many organs. He maintains these nerves are visceral sensory nerve endings, because their peripheral structures are morphologically similar to those of the somatic sensory nerves.

In agreements with these opinions, the author sought for the sensory nerves in the urinary organs.

The "Terminalreticulum" (STOEHR) or the "Nervoeese Synzytium" (JABONERO) : found in various portions of the urinary organs. But besides them, there are also thick nerve fibers, which terminate freely in the periphery. These thick nerve fibers are myelinated. They show clear degeneration nearly to their endings when they are sectioned at the posterior roots. Judging from these facts, these thick nerve must be sensory in nature.

As for the visceral sensory innervation of the urinary organs, it has been described by LEHMANN, NEUMANN, ASAI, KUBO, KAWAKAMI, YOSHIKE and others from the physiological point of view. Histological studies of sensory nerves in various viscera have been reported by many investigators of our clinic ; i. e., TANAKA in the esophagus, OTSU in the stomach, INOUE in the biliary tract, MAKINO in the small intestine, I in the colon, WANG in the sigmoid and rectum, SATO in the ovary and OTSUJI in the testis. According to them, sensory nerves which consist of myelinated nerve fibers are proved in these organs. The results of my experiments in the urinary organs are in agreement with their results.

The author found sensory nerve endings in various portions of the kidney, the ureter, and the urinary bladder. A few sensory nerve endings are found in the kidney, more in the ureter and very numerous in the bladder.

These sensory nerve endings show simple-shaped or arborized terminations. Sensory nerve endings are considered to form a complicated structure or specific end-apparati, such as the Vater-Pacinian corpuscle described by KUNTZ in the bladder. But the author could not find such forms of sensory endings.

In the ureter of ureterolithiasis, sensory nerve fibers in the submucous layer are more abundant than in the normal ureter, but some of them are broken or swollen in places. These morphological changes of sensory nerve fibers may be due to the inflammation of the ureter.

In regard to the sensory innervation of the urinary organs, KUNTZ described that the afferent nerve fibers in the kidney are mainly derived from the 10th., 11th. and 12th. thoracic nerves. According to the physiological experiments performed by YOSHIKE, sensory nerves of the kidney arise from the dorsal roots of the spinal cord between Th. 9-Th. 10, and those of the ureter between Th. 11-L. 1 and S. 1.

The results of the histological experiments performed by the author are as follows :

Sensory nerves of the kidney are derived from the dorsal roots of the spinal segments between Th. 5-L. 4 ; most of them from Th. 9-L. 1. In the ureter they are derived from Th. 8-L. 4 and S. 1-S. 3, and most of them from Th. 12-L. 1. In the bladder, they are derived from L. 1-L. 4 and S. 1-S. 3, and most of them from S. 1-S. 3.

In case of the section of the dorsal roots on the right side, no degenerated nerve fibers were found in the kidney and the ureter of the opposite side, but in the wall of the bladder on the opposite side few degenerated nerve fibers were observed. This fact shows that sensory nerves of the kidney and the ureter are derived only from the dorsal roots of the spinal cord on the homolateral side, and those of the bladder

from both sides.

The section of the ventral roots of the spinal cord between S. 1—S. 3 on the right side caused degeneration in the bladderwall mainly on its right side and a few on the left side. Therefore, some of the sensory nerves must be derived from the bilateral ventral roots of the spinal cord.

As for the dominant innervation of sympathetic and parasympathetic afferents in the kidney, thoracolumbar, i. e., sympathetic innervation is more dominant than that of the vagal afferents. In regard to the ureter, the thoracolumbar is more dominant than that of the sacral. But in the bladder, especially in the trigonum, sacral innervation is more dominant than that of the thoracolumbar nerves.

The dual (sympathetic and parasympathetic) afferent innervations of the spinal segments are proved in the urinary organs.

S. W. RANSON described that non-myelinated visceral afferent fibers exist in the sympathetic trunk; T. KURE insisted on the existence of sensory nerves in the spinal parasympathetic system, and STOEHR maintained that sensory nerves are contained in the "Terminalreticulum". They may be true, but the author cannot find any suitable method to prove the existence of such sensory nerves.

VI SUMMARY AND CONCLUSION

Using EHRlich's acid hematoxyline method and modified BIELSHOWSKY's method, the author studied the afferent nerves and their endings in the urinary organs of human beings and dogs. Examining the secondary degeneration of nerves in the urinary organs after section of the nerve trunks, the course of the afferent innervation of the urinary organs was determined.

Summarizing the results of the experiments, the following conclusions are obtained.

- 1) Myelinated nerve fibers and sensory nerve endings are observed in the urinary organs of human beings and dogs.
- 2) Sensory nerve endings are simple tapering or bifurcated freeending terminations.
- 3) At least some sensory nerves have myelin sheaths even near the termination.
- 4) No sensory nerve endings with a complicated structure or specific end-apparati are observed in the urinary organs.
- 5) Most of the sensory nerves of the kidney are derived from the dorsal roots between Th. 5—L. 4 spinal segments, but some of them from the vagus nerve. Sensory nerves of the ureter are derived from the dorsal roots between Th. 8—L. 4 and S. 1—S. 3 spinal segments.
- 6) Most of the afferent nerves of the bladder of dogs are derived from the dorsal roots of the homolateral side between L. 1—L. 4 and S. 1—S. 3, and a few of them from the dorsal roots of the opposite side between L. 1—L. 4. and S. 1.—S. 3.
- 7) Few of the afferent nerve fibers of the urinary bladder of dogs are derived from the ventral roots of the homolateral or opposite side between S. 1-S. 3.

8) As for the dominancy of the afferent innervation of the urinary organs, thoracolumbar innervation is more dominant in the kidney than that of the vagus nerve; thoracolumbar innervation is more dominant in the ureter than sacral innervation; sacral innervation is more dominant in the bladder than thoracolumbar innervation.

9) Dual afferent innervations, i. e, sympathetic and parasympathetic afferents, are proved in the urinary organs.

10) In the specimens of ureterolithiasis, many abnormal sensory nerves are observed, i. e, some of them are broken on their course, and others swell in places.

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Study of Sensory Nerve Ending in the Alimentary Canal of the Humanbeings and Dogs. *Acta Sch. Med. Univ. Kyoto*, Jap. 31, 1953. 27) Otsuji, S., A Histological Study of the Afferent Innervation of the Testis of the Dog. *Arch. f. jap. Chir.* 24, 1955. 28) Ranson, S. W., *The Autonomic Nervous System*. 1946. 29) Ranson, S. W., Foley, J. O., and Alpert, C. D., Observation of the Structure of the Vagus Nerve. *Am. Jour. Anat.* 53, 1933. 30) Renner, O., *Dtsch. Arch. Klin. Med.* 110; 101, 1913. 31) Smirrnnow, A.E., *A.E. Anatom. Anzeiger* 19; 347, 1901. 32) Seto, H., *Progress of Medicine*. 5, 1949. 33) Seto, H., *The Tohoku Journal of Experimental Medicine*. 40, 1949. 34) Seto, H., *Histological Studies on the Sensory Terminations distributed in the Circulatory System and the Urogenital Organs. Kaibogaku Zasshi*, 29; 2, 1954. 35) Stoehr, Jr. P., *Lehrbuch der Histologie und der mikroskopische Anatomie des Menschen*. Springer-Verlag, 1951. 36) Stoehr, Jr. P., *Mikroskopische Anatomie des vegetativen Nervensystem*. 1951. 37) Stoehr, Jr. P., *Zusammenfassende Ergebnisse über die Endungsweise des vegetativen Nervensystems. Acta Neuro-Veg.* X, 1954. 38) Sunderplasmann, P., *Deutsche Zeisschrift für Chirurgie*. 224, 1935. *Deutsche Zeitschrift für Chirurgie*. 240, 1933. 39) Sato, H., *A Histological Study of the Afferent Innervation of the Ovary of the Dog. Arch. f. jap. Chir.* 24, 1955. 40) Tanaka, N., *A Histological Study of the Dual Afferent Innervation of the Esophagus of the Dog. Arch. f. jap. Chir.* 22, 5, 1953. 41) Weddell, G., and Sinclair, D. C., *The Anatomy of Pain Sensibility. Acta Neuro-Veg.* VII, 1953. 42) White, J. C., Smithwick, R. H., and Simeone, F. A., *The Anatomic Nervous System*, 3rd Edition, 1952. 43) Wang wei Fan., *A Hstiological Study of the Afferent Innervation of the Sygma and Rectum. Arch. f. jap. Chir.* 24, 1955. 44) Yoshiike, Y., *Physiologic Studies on the Visceral Sensation of the Urogenital Organs. Arch. f. jap. Chir.* 23, 1954. 45) Zimmermann, R., *Experimentelle Untersuchungen über die Empfindungen in der Schlindröhre und im Magen, in der Harnröhre und in der Blase und im Enddarm. Grenzged. Med. u. Chirurg.* 1909,

Seto's method

The specimens, which have been sliced with the freezing method and kept in 10% neutral formol solution, are

- 1) Washed with distilled water for a few minutes,
- 2) Put into 20% silver nitrate solution, being protected from light, for 24~48 hours,
- 3) Washed in distilled water for 20~30 seconds,
- 4) Put into 20% neutral formol solution.

This solution should be made only by diluting the mother neutral formol by all means with running water. This formol solution is then divided into 4 to 3 plates. And then the specimens are transferred one by one from the first plate to last until the white precipitation disappears.

- 5) Washed with running water for 30~50 seconds,
- 6) Placed on filter paper to blot up the water,
- 7) Put into warm ammoniacal silver solution for about 10 minutes,
- 8) Washed with distilled water twice,
- 9) Placed in 0.05~0.1% gold chloride solution for 3~4 hours,
- 10) Washed in distilled water for a few minutes,
- 11) Placed in 20% sodium thiosulfate solution until the specimens are colored reddish brown,
- 12) Washed in destilled water,
- 13) dehydrated and mounted.

SUZUKI's method

The specimens, which have been sliced with the freezing method and kept in 10% neutral formol solution, are

- 1) washed 3 times with distilled water, each time for about 10 minutes,
- 2) put into 20% silver nitrate solution for about 24 hours, in the darkness,
- 3) Washed with distilled water for a few seconds,
- 4) put into ammoniacal silver solution untill the specimens were colored light yellow,
- 5) placed in 10% sodium-potassium tartrate solution for a few minutes untill the specimens were colored gold yellow,
- 6) washed with distilled water for a few minutes,
- 7) placed in 0.05~0.1% gold chloride solution for 1~2 hours,
- 8) washed with distilled water a few minutes,
- 9) placed in 20% soldium thiosulfate solution,
- 10) Washed in distilled water,

11) dehydrated and mounted.

Abbreviation.

B. BIELSCHOWSKY'S method.

E. EHRLICH'S method.

H. Human being.

D. Dog.

和文抄録

泌尿器系に於ける知覚神経に関する組織学的研究

京都大学医学部外科学教室第2講座（指導 青柳安誠 教授）

大学院学生 吉 田 恒 雄

Bielschowsky 氏神経鍍銀法の瀬戸氏変法，鈴木氏変法及び Ehrlich 氏神経髄鞘染色法を用い，人及び犬の新鮮なる腎臓，輸尿管，膀胱の標本に於て，知覚神経の形態及び分布を検索し，更に迷走神経，脊髓後根，脊髓前根を両側或は偏側に於て実験的に切断せる犬に於て，腎臓，輸尿管，膀胱組織内の末梢神経の二次的変性を追求し，之等の結果より，腎臓，輸尿管，膀胱の知覚神経に就て次の結論を得た。

1) 有髄神経は，腎臓，輸尿管，膀胱に於ても相当数に存在し，末梢近くにまで分布せるのを認めた。その数的関係は，膀胱が最も多く，次に腎臓，輸尿管の順である。

2) 知覚神経も，腎臓，輸尿管，膀胱に認められ，その数的関係は，有髄神経繊維と同様の順序である。

3) 知覚神経の終末形式は，非分岐性並に単純性樹枝状の終末にて，特殊終末形式は発見されなかつた。

4) 之等の知覚神経終末は，腎臓に於ては，主として葉間血管壁，小葉間血管壁，及び血管襻周囲に認められ，輸尿管，膀胱に於ては，主に粘膜下層，粘膜層に発見され，一部は筋層に発見された。膀胱に於ては，特に三角部に於て多数の知覚神経が認められた。

5) 犬の腎臓を支配する知覚神経は，脊髓後根 Th.

5—L.4 を通るが，大部分は Th.9—L.1 を通る。1部ごく少数の知覚神経は迷走神経を通る。

6) 犬の輸尿管を支配する知覚神経は，脊髓後根 Th. 8—L.4 及び S.1—S.3 を通るが，大部分は Th.12—L.1 を通る。

7) 犬の膀胱を支配する知覚神経は，脊髓後根 L.1—L.4 及び S.1—S.3 を通る。更に極く少数乍ら，S.1—S.3 の前根を通る知覚神経も認められたが，大部分 S.1—S.3 の後根を通る。

8) 腎臓及び輸尿管の知覚神経は同側の脊髓後根を通るが，膀胱の知覚神経は大部分が同側の脊髓後根及び前根を通るが，一部は反対側の脊髓後根及び前根を通る。

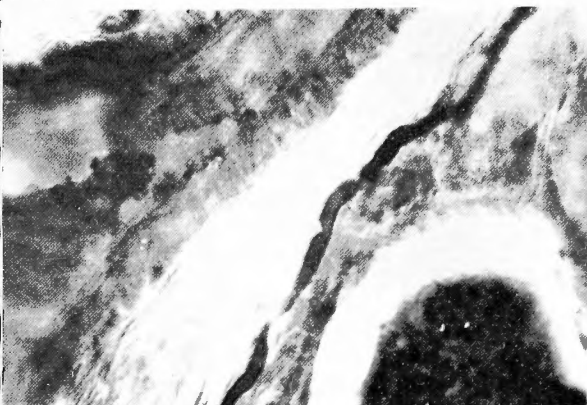
9) 腎臓，輸尿管，膀胱は，交感性，副交感性二重知覚神経支配を受けている。腎臓は胸腰髄性知覚支配が迷走知覚支配より優勢であり，輸尿管は，胸腰髄性知覚支配が仙髄性知覚支配より優勢であり，膀胱に於ては，仙髄知覚支配が胸腰髄性知覚支配より優勢である。

10) 人の輸尿管結石症の標本に於て，異常知覚神経が発見された。この神経繊維は所々断裂されたり，或は所々膨隆している。

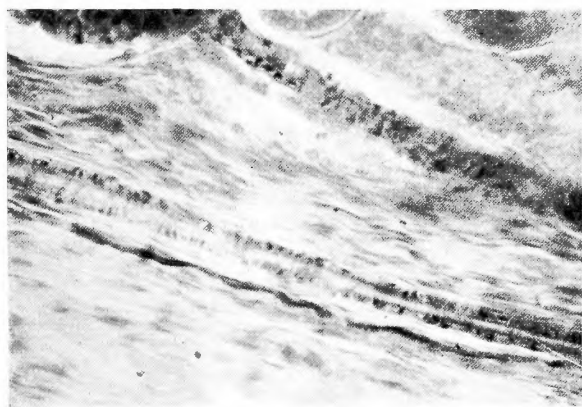
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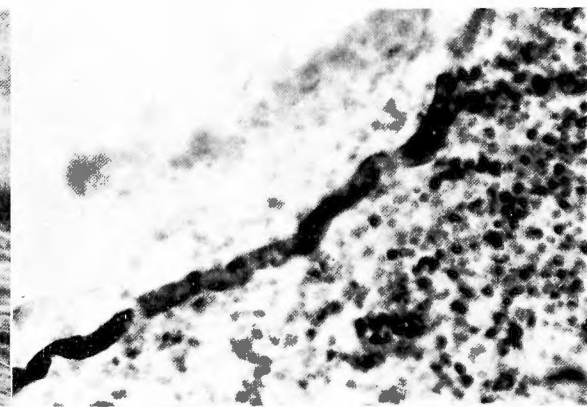
1) Myelinated nerve fibers along the interlobular artery in the kidney (3μ in diameter) (Dog) $\times 200$ EHRLICH's hematoxylin method.



2) Myelinated nerve fiber along the interlobular artery in the kidney (D) $\times 600$ E.



3) Myelinated nerve fiber along the vasa afferentia (2μ in diameter) (D) $\times 400$ E.



4) Large-sized myelinated fiber in the mucous layer of the renal calyx (9μ in diameter) (D) $\times 400$ E.

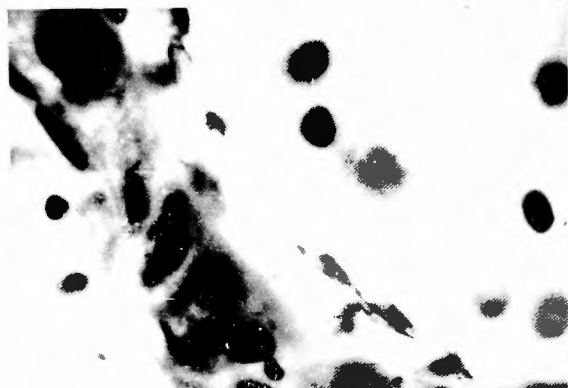


5) Myelinated nerve fiber in the renal capsule (4μ) (D) $\times 600$ E.

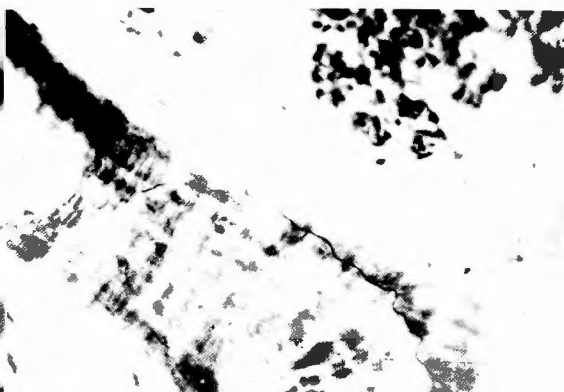


6) The "Terminalreticulum" in the renal cortex (Human being) $\times 1200$ BSIELSCHOWSKY's method.

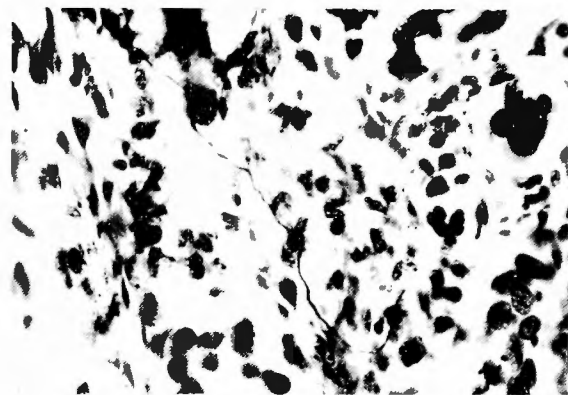
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7) The "Terminalreticulum" along the interlobular artery (H) × 400 B.



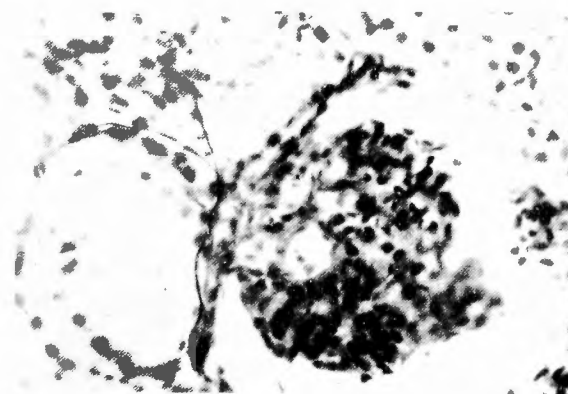
8) Sensory nerve fiber along the interlobular artery (H) × 400 B.



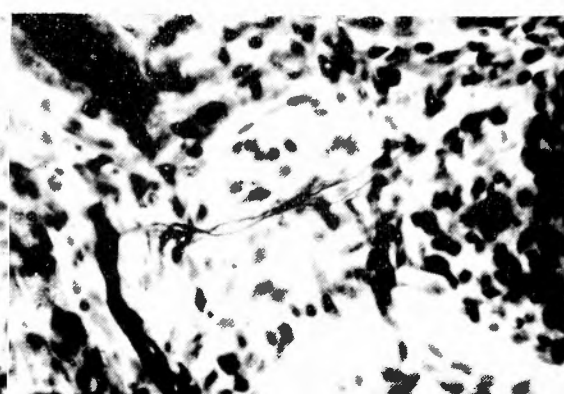
9) Sensory nerve fiber along the interlobular artery (H) × 400 B.



10) Sensory nerve fiber around the Bowman's capsule (H) × 1200 B.

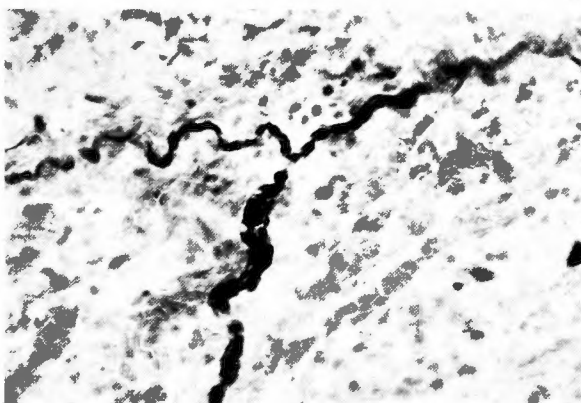


11) Sensory nerve fiber around the Bowman's capsule (H) × 400 B.

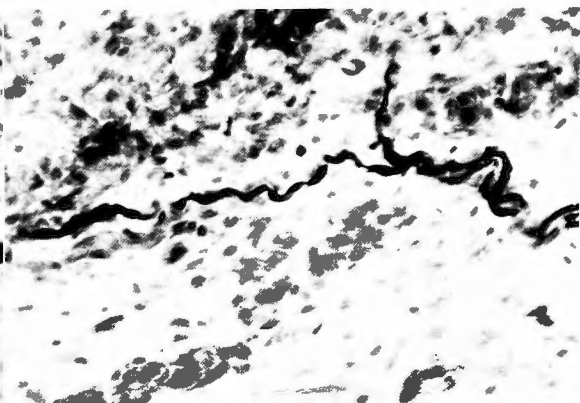


12) Sensory nerve fibers entering the glomerulus (H) × 400 B.

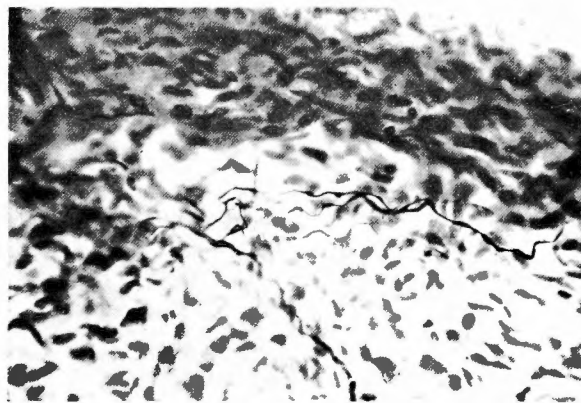
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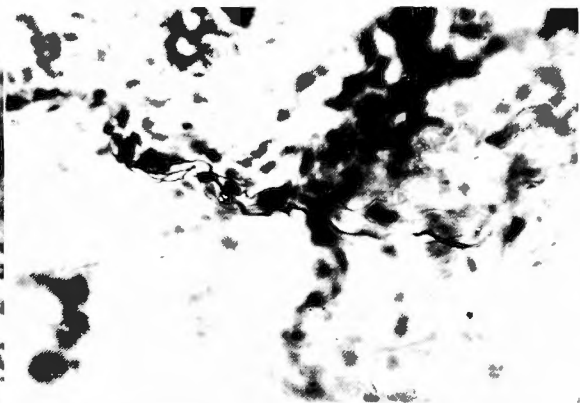
13) Myelinated nerve fibers in the mucous layer of the upper portion of the ureter ($4\mu-2\mu$ in diameter) (D) $\times 400$ E.



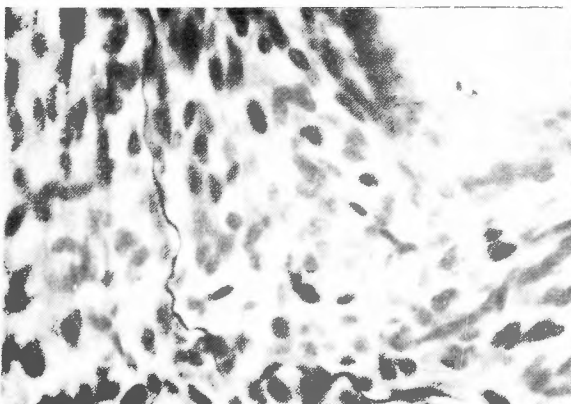
14) Myelinated nerve fibers in the mucous layer of the lower portion of the ureter (3μ in diameter) (D) $\times 400$ E.



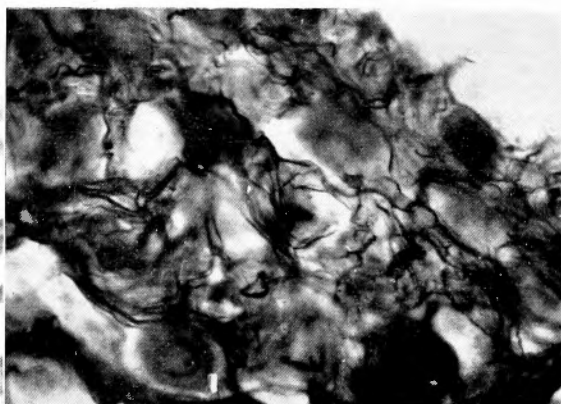
15) Sensory nerve fibers in the mucous layer of the upper portion of the ureter (D) $\times 400$ B.



16) Sensory nerve fibers in the submucous layer of the middle portion of the ureter (H) $\times 400$ B.



17) Sensory nerve fibers in the submucous layer of the lower portion of the ureter (D) $\times 400$ B.

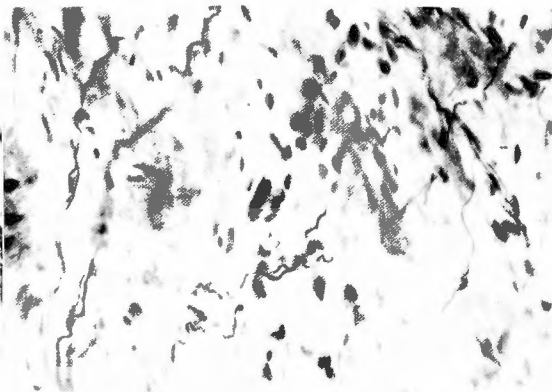


18) Ganglion in the muscular membrane of the lower portion of the ureter (D) $\times 600$ B.

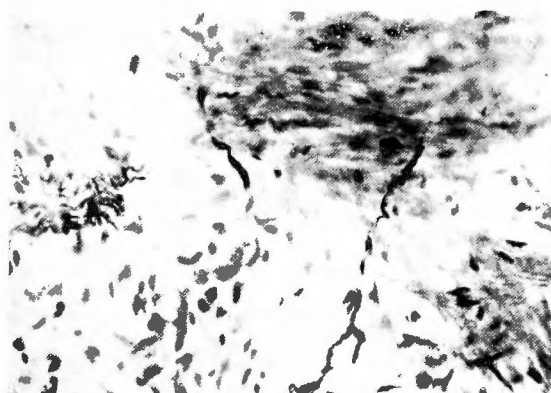
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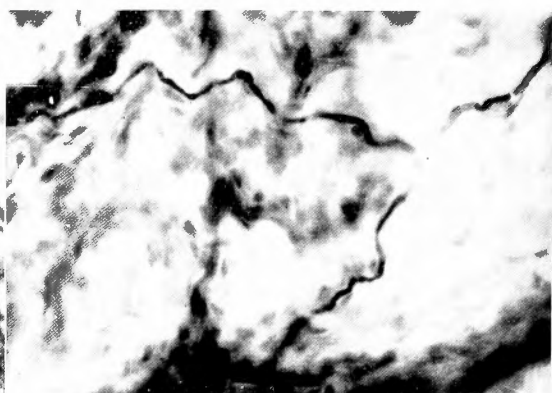
19) Abnormal nerve bundle in the submucous layer of the ureter suffering from ureterolithiasis (H) $\times$ 400 B.



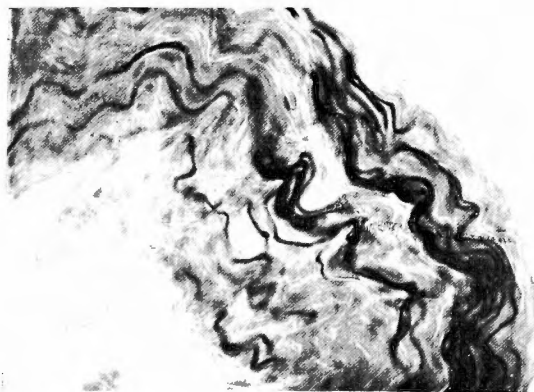
20) Many sensory nerves in the submucous layer of the ureter suffering from ureterolithiasis. (H) $\times$ 400 B.



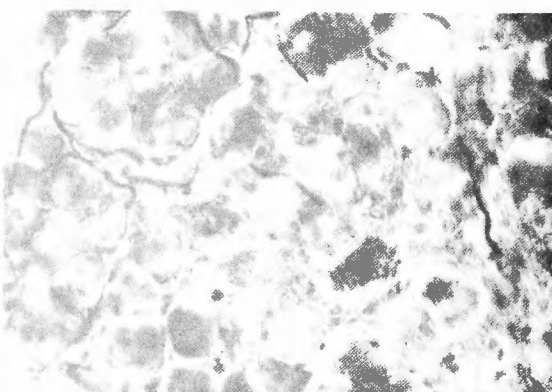
21) Abnormal degenerated sensory nerves in the submucous layer of the ureter suffering from ureterolithiasis (H) $\times$ 400 B.



22) Myelinated nerve fibers in the submucous layer of the bladder (3 μ in diameter) (H) $\times$ 400 E.

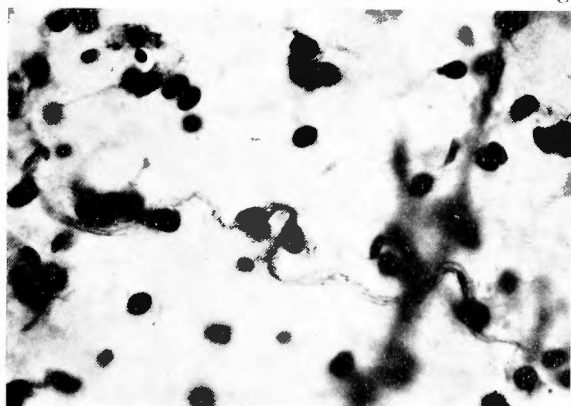


23) Large myelinated nerve bundle in the muscular layer of the bladder (D) $\times$ 400 E.

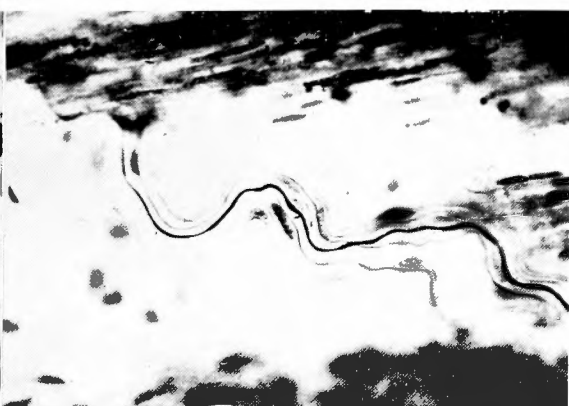


24) Nerve cells in the muscular layer of the bladder (D) $\times$ 400 E.

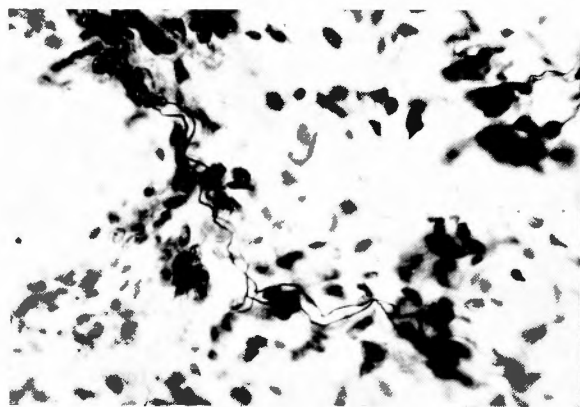
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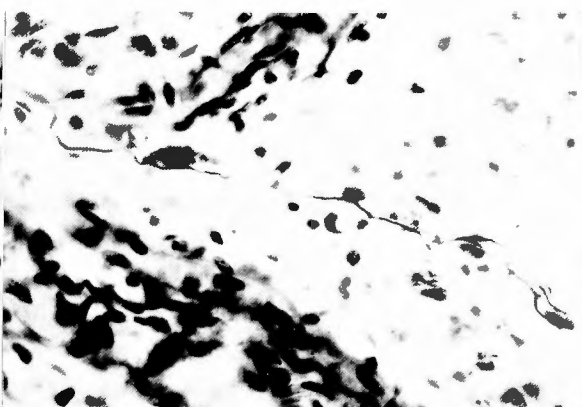
25) "Nervöse Synzytium" in the submucous layer of the bladder (D) $\times$ 400 B.



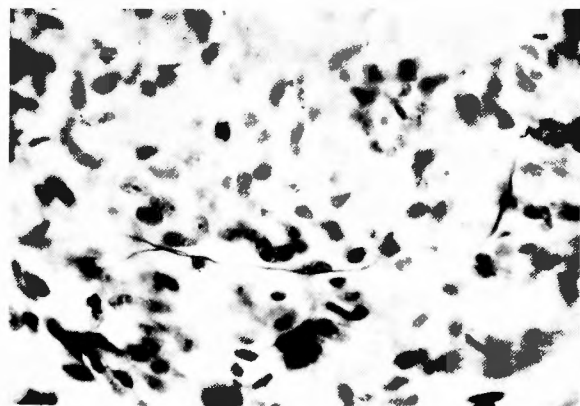
26) Sensory nerve in the muscular layer of the bladder accompanied with autonomic nerves (H) $\times$ 400 B.



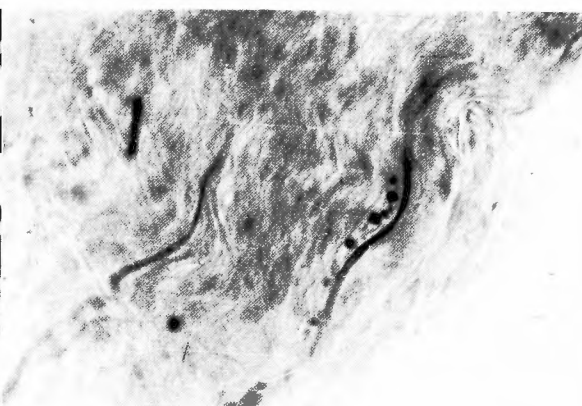
27) Sensory nerve fibers in the submucous layer of the trigonum of the bladder (H) $\times$ 400 B.



28) Sensory nerve fibers in the submucous layer of the lateral wall of the bladder (D) $\times$ 400 B.

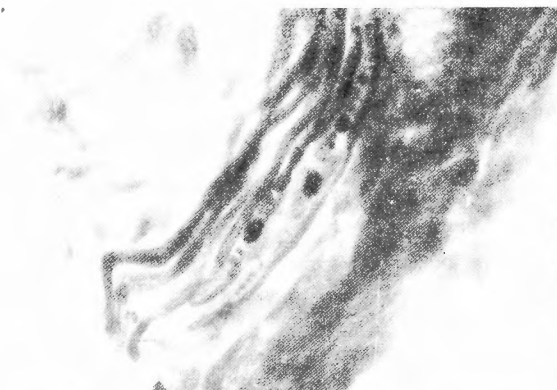


29) Sensory nerve fiber in the epithel of the trigonum of the bladder (D) $\times$ 400 B.

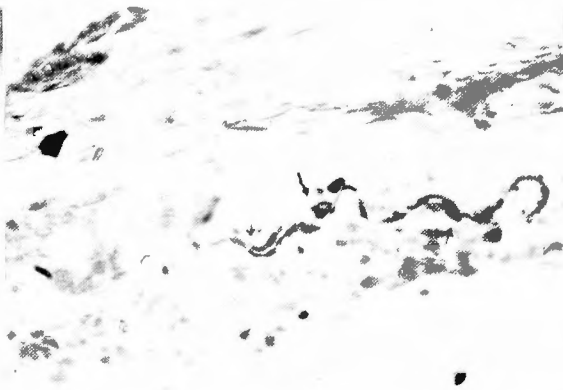


30) A degenerated nerve fiber in the hilum of the kidney with posterior rhizotomy on both sides (Th. 5-Th. 6) (D) $\times$ 400 E.

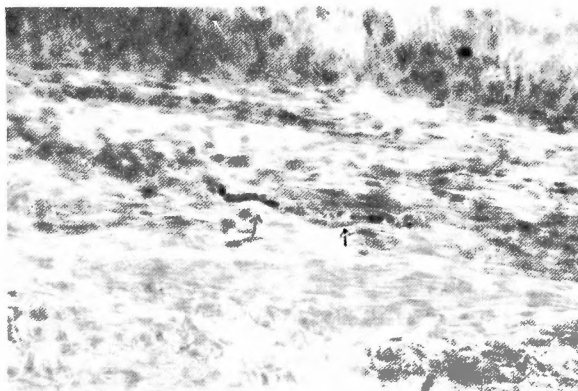
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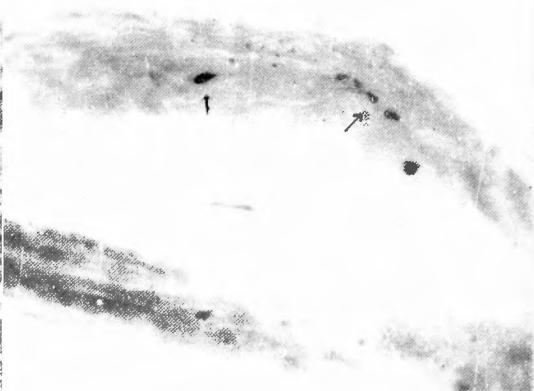
31) Degenerated nerve fibers in a nerve bundle in the hilum of the kidney with posterior rhizotomy on both sides (Th. 10-Th. 12) (D) $\times$ 400 E.



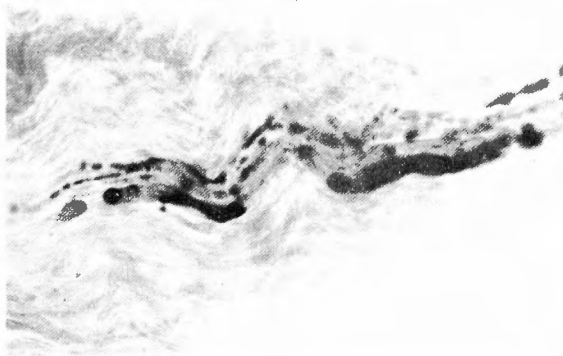
32) A degenerated nerve fiber in the subserous tissue of the upper portion of the ureter with posterior rhizotomy on both sides (Th. 10-Th. 12) (D) $\times$ 400 E.



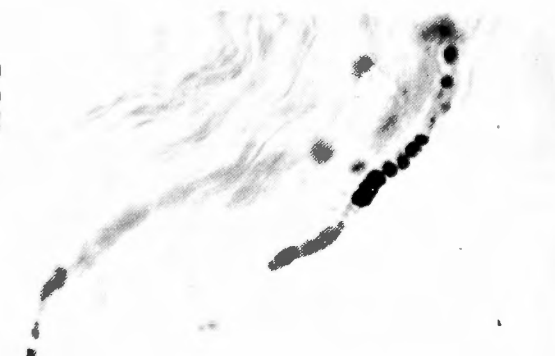
33) A degenerated nerve fiber in the submucous layer of the upper portion of the ureter with posterior rhizotomy on both sides (Th. 10-Th. 12) (D) $\times$ 400 E.



34) A degenerated nerve fiber in the renal capsule with posterior rhizotomy on both sides (Th. 10-Th. 12) (D) $\times$ 400 E.

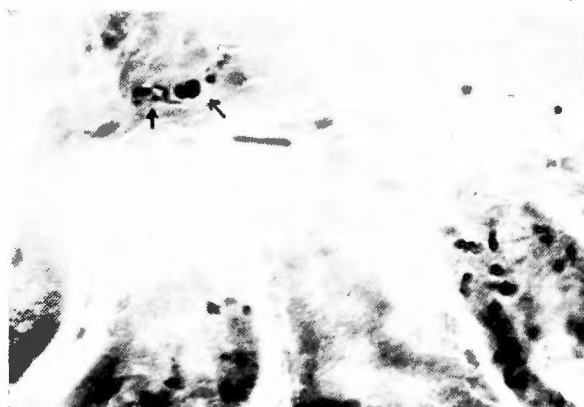


35) Many degenerated nerve fibers in a nerve bundle along the interlobar blood vessel of the kidney with post. rhiz. on both sides (Th. 13-L. 1) (D) $\times$ 400 E.

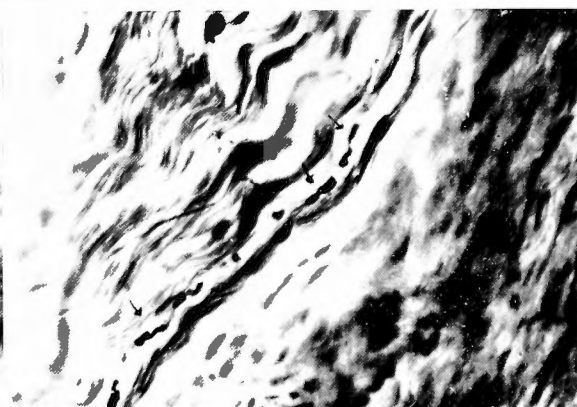


36) Many degenerated nerve fibers in a nerve bundle along the interlobar blood vessel of the kidney with post. rhiz. on both sides (Th. 13-L. 1) (D) $\times$ 400 E.

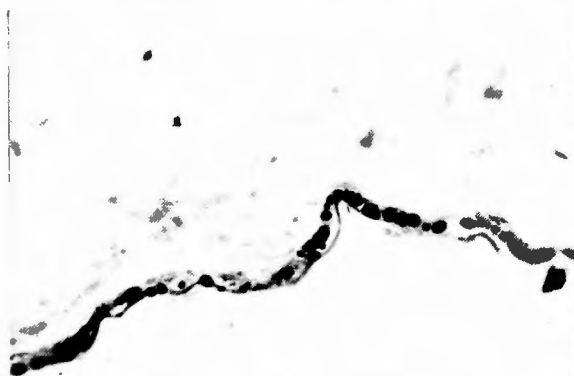
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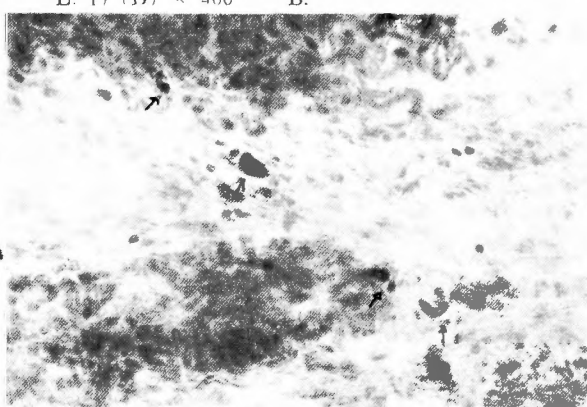
37) A degenerated nerve fiber along the interlobular blood vessel of the kidney with post. rhiz. on both sides (Th.13-L. 1) (D) $\times$ 400 E.



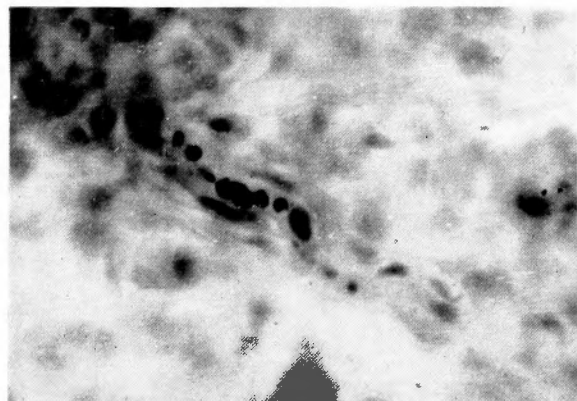
38) Degenerated nerve fibers in a nerve bundle along the interlobar blood vessel of the kidney with post. rhiz. on both sides (Th. 13-L. 1) (D) $\times$ 400 B.



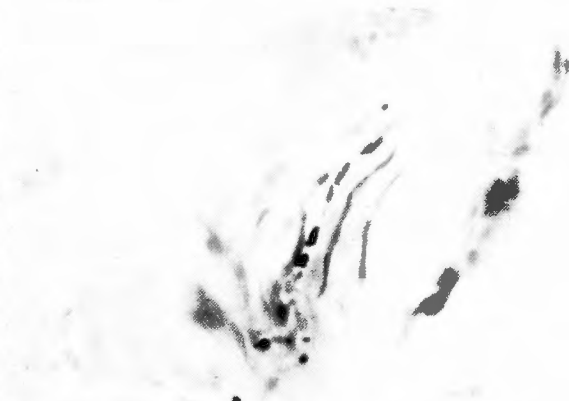
39) A degenerated nerve fiber in the subserous tissue of the middle portion of the ureter with post. rhiz. on both sides (Th. 13-L. 1) (D) $\times$ 400 E.



40) A degenerated nerve fiber entering the mucous layer of the middle portion of the ureter with post. rhiz. on both sides (Th. 13-L. 1) $\times$ 400 E.

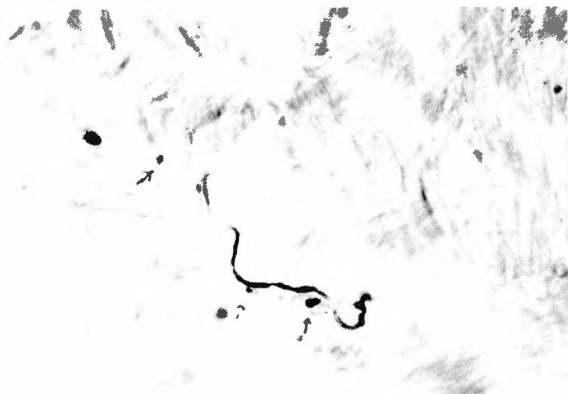


41) A degenerated nerve fiber in the mucous membrane of the lateral wall of the bladder with post. rhiz. on both sides (L.2-L.1) $\times$ 400 E.

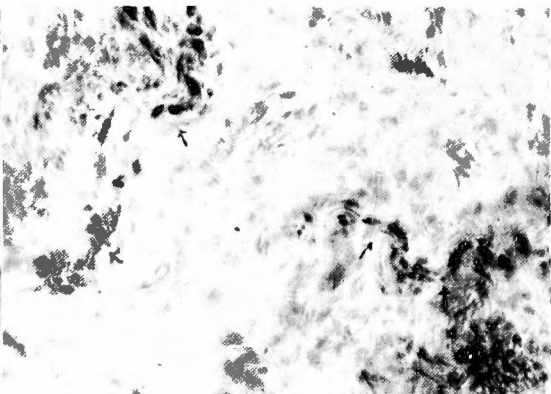


42) A degenerated nerve fiber in a nerve bundle in the muscular layer of the trigonum with post. rhiz. on both sides (L. 2-L. 4) (D) $\times$ 400 E.

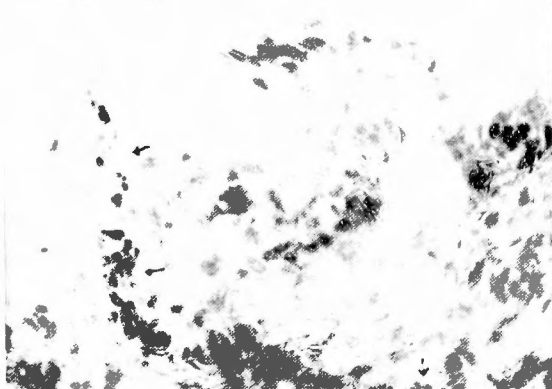
Figures



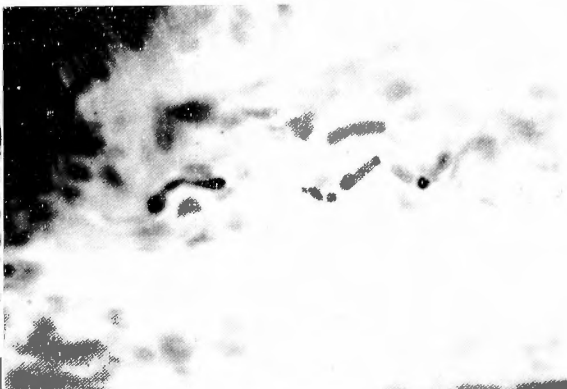
43) A degenerated nerve fiber in the muscular tissue of the upper portion of the ureter with post. rhiz. on both sides (S. 1-S. 3) (D) $\times 400$ E.



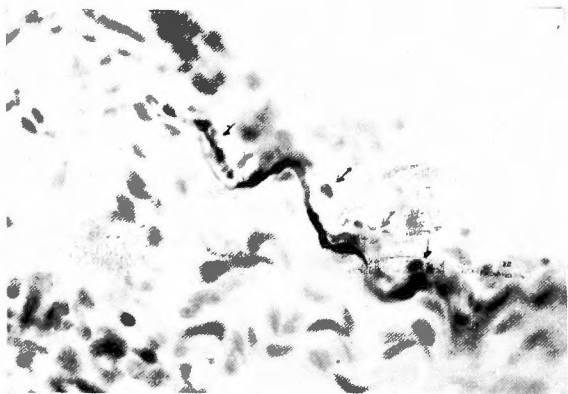
44) Degenerated nerve fibers in the mucous membrane of the trigonum with post. rhiz. on both sides (S. 1-S. 3) (D) $\times 400$ E.



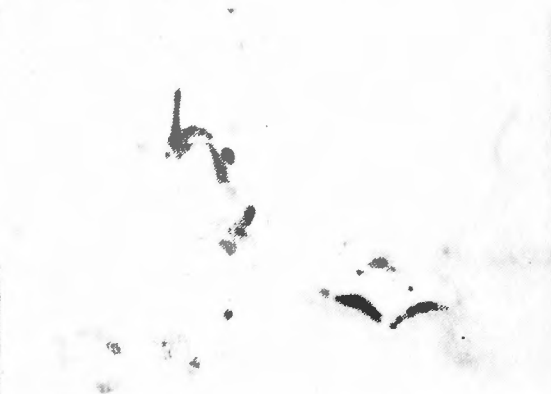
45) A degenerated nerve fiber in the sub-mucous layer of the trigonum with post. rhiz. on both sides (S. 1-S. 3) (D) $\times 400$ E.



46) A degenerated nerve fiber in the muscular layer of the opposite side of the trigonum with right posterior rhizotomy (S. 1-S. 3) (D) $\times 400$ E.



47) A degenerated nerve fiber in the mucous layer of the right side of the trigonum with right anterior rhizotomy (S. 1-S. 3) (D) $\times 400$ E.



48) A degenerated nerve fiber in the hilum of the kidney with vagotomy in the thorax (D) $\times 400$ E.