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Author(s)	TAKEDA, HARUO
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A HISTOLOGICAL STUDY OF THE INNERVATION OF THE URETHRA AND THE SPHINCTERS OF THE URINARY BLADDER OF THE DOG

by

Haruo Takeda

From the 2nd Surgical Division, Kyoto University Medical School
(Director: Prof. Dr. Yasumasa Aoyagi)

CONTENTS

I. INTRODUCTION

The normal act of micturition is dependent upon a well-sustained contraction of the smooth musculature and relaxation of the sphincter muscles of the urinary bladder. It is clinically evident that lesions of the nervous system affecting micturition cause disorders of contraction and disturbances in urination such as retraction, protraction, retention and incontinence of urine, and it is also accepted that disease of the urethra and alteration in the nature of the urine often cause urethral pain.

Denny-Brown, Robertson, Langworthy, Kolb, Evans, Zimmerman and many other investigators have done research on the physiology of micturition. From their evidence, desire to urinate is derived from passive distension of the bladder, which causes contraction of the bladder musculature and relaxation of the internal (involuntary) sphincter. The closure of this sphincter is definite, and is continuously maintained during intervals of slight or absent vesical contraction. The external (voluntary) sphincter is also kept closed and opens only after the opening of the internal sphincter. It closes spontaneously at the termination of micturition before the internal sphincter has closed. It appears not to be relaxed by voluntary effort.

From the physiological standpoint, Lehmann, Neumann, Asai, Kawakami, Kimura and Yoshiike have already proved the existence of sensitivity in the pelvic viscera, and have maintained that the sensitivity is mediated through the sympathetic and pelvic nerves. Denny-brown, Langworthy and Kolb have confirmed that the pudic nerves carry sensory fibres from the external sphincter and posterior urethra and motor fibres to the external sphincter.
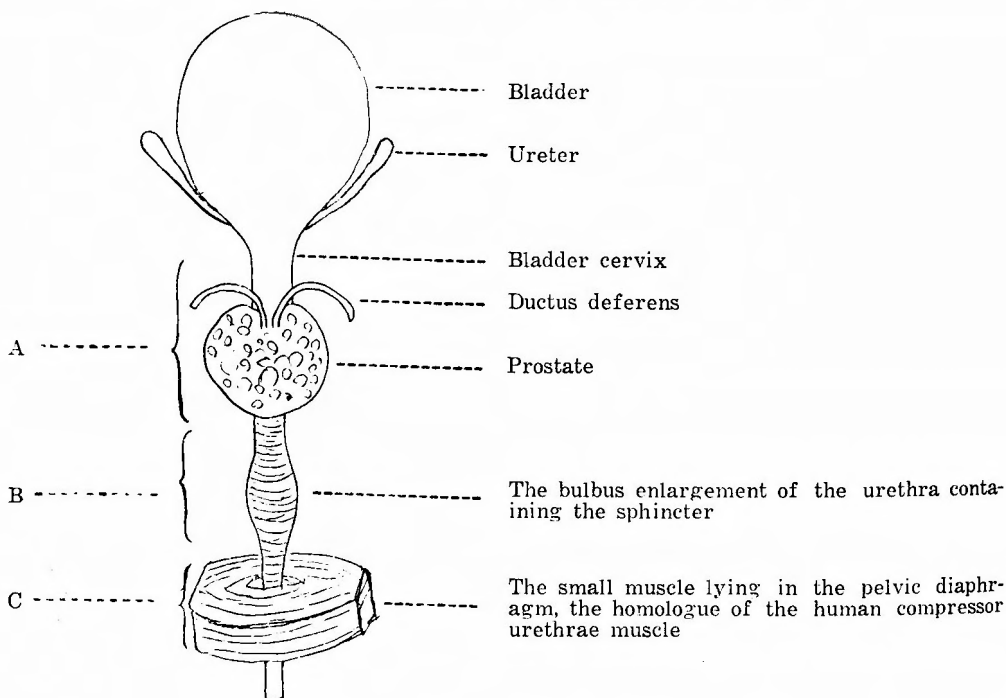
From the histological viewpoint, KUNTZ, WHITE and FUKUYAMA have confirmed that the visceral afferent nerve fibres are certainly contained in the sympathetic, pelvic and pudic nerves. SETO, YOKOYAMA and YOSHIDA observed sensory nerves in the urinary bladder, WATANABE, YAMADA and MORI in the urethra of the female dog, and OJIMA in the urethra of the cat. But no investigator has studied histologically the innervation of the sphincter muscles of the urinary bladder.

In this histological study, the author looked for sensory nerve endings in the urethra, motor and sensory nerve endings in the sphincters, and then conducted experiments in order to determine the course of these nerves.

II. MATERIALS AND METHODS

The anatomical relationships of the bladder and urethra of the dog are shown in the diagramatic drawing (Fig. 1). A long bladder neck extends in the male to the prostate and in the female to a bulbus muscular expansion. In each sex this segment of the urethra extending as far as the pelvic fascia constitutes the first portion of the urethra and here lies the compressor urethrae muscle······ the true external sphincter. It should be noted that the muscle bearing this name constitutes a muscular investment of the first portion of the urethra, and is not homologous to the muscle of the same in man. The small muscles lying in the pelvic diaphragm are the homologue of the human compressor urethrae muscle. In the dog there appears to be no distinct internal sphincter, for direct observation shows

Fig. 1. Diagramatic representation of the urethra in the male dog

Bladder

Ureter

Bladder cervix

Ductus deferens

A

Prostate

B

The bulbus enlargement of the urethra containing the sphincter

C

The small muscle lying in the pelvic diaphragm, the homologue of the human compressor urethrae muscle

the entire bladder neck to act in this capacity. The muscularis of the bladder neck consists of a median annular layer and outer and inner longitudinal layers; the former is strong but the latter two are relatively poor in development.

From this anatomical viewpoint all the materials used in my study were obtained from adult male dogs. Under general anesthesia with sodium isomytal, the urethra and internal sphincter (A) and the external sphincter (B and C) were resected operatively, and fixed in 10 % neutral formol solution for 3~4 weeks. The specimens were sliced with the freezing microtome into frozen sections of 35~40μ thickness, and further fixed in 10 % neutral formol solution for 2~4 months, and then submitted to impregnation.

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.

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 pelvic viscera pass through the lumbosacral nerves. J. N. Langley have maintained that visceral afferent nerves have their cell-stations in the dorsal ganglia of the spinal cord, and Neumann and Nitta have proved that some afferent nerve fibres arise from the ventral roots of the spinal cord. The nerve cells of motor nerves innervating skeletal muscles lie in the anterior horn of the spinal cord, and the postganglionic fibres have no interposing nerve cells till their terminations.

Hence, the spinal nerves were sectioned at various points to determine experimentally the course of the afferent and efferent nerves of the urethra and sphincters. Operations were separately carried out on the dorsal or ventral roots of the spinal cord distal to spinal ganglia, with some exceptions in which both anterior and posterior roots were cut together. In some animals the pudic nerves were sectioned. Degenerated nerve fibres and motor end-plates were observed in the specimens. Specimens were extirpated 3~7 days after operation, considering the results of the investigators of our clinic that axis-cylinders have degenerated by 3~4 days after, and myelin sheaths have degenerated by 5~6 days after the section of the spinal nerves.

Operations were performed as follows:
1) Section of the dorsal roots on both sides (L. 1······L. 3)
2) Section of the dorsal roots on both sides (L. 4······L. 7)
3) Section of the dorsal roots on both sides (S. 1······S. 3)
4) Section of the dorsal roots on the right side (L. 1······L. 3)
5) Section of the dorsal roots on the right side (S. 1······S. 3)
6) Section of the ventral roots on the right side (L. 1······L. 3)
7) Section of the ventral roots on the right side (L. 4······L. 7)
8) Section of the ventral roots on the right side (S. 1······S. 3)
9) Section of the right pudic nerve

III. MICROSCOPICAL OBSERVATION

1) Urethra :

The urethra receives its nerve supply from the hypogastric, pelvic and pudic nerves and thus has many nervous elements.

The development of the nerve plexus in the muscularis and the submucous layer of the urethra is incomparably poorer than that in the intestines, and ganglia are rarely seen in the bladder neck and membranous portion of the urethra (Fig. 1). Numerous autonomic terminations are beautifully demonstrated around the capillaries in the propria (Fig. 2).

Many myelinated nerves are observed more than in the bladder (YOSHIDA). Myelinated nerve fibres, being accompanied by non-myelinated nerve bundles, enter the muscularis along the urethral vessels and arborize either in the propria or in the epithelium. Myelinated nerve fibres are mostly small-(less than 3μ in diameter), but a few are medium-sized ($4 \sim 6\mu$ in diameter) and very few are large (more than 7μ in diameter) (Fig. 3, 4, 5).

In the preparations stained with silver impregnation, the axis-cylinders show a similar distribution to the myelinated nerve fibres. Thick nerve fibres, which are found beside the autonomic nerve fibres mentioned above, are distributed along capillaries and terminate freely in the propria and in the epithelium (Fig. 6). These nerve fibres are easily distinguished from the autonomic nerve fibres by their thickness and varicosities.

In the propria these nerve fibres are either unbranched or simply branched and sometimes glomerular-shaped. Glomerular types generally originate in thick nerve fibres and the inner bulb in the connective tissue capsule has special cells, which are considered to originate from SCHWANN's cells. These terminations are named genital nerve corpuscles. In the posterior urethra the number of these corpuscles is smaller and their structure is simpler than in the anterior urethra (Fig. 7, 8, 9).

Intraepithelial fibres run in wavy courses not only in the transitional epithelium but also in the stratified columnar epithelium. They are either unbranched or simply branched, and consist in most cases of small or medium-sized fibres, but in some cases of large-sized fibres, though they become thinner in their course (Fig. 10, 11). These fibres seem to terminate in free ending (Fig. 13, 14), but sometimes they change into fine fibrils forming expansions at the endings (Fig. 12)·

2) Internal sphincter :

The internal sphincter has a structure and nerve supply similar to the musculature of the bladder (YOSHIDA).

Autonomic nerve plexuses are poor in development and very rarely contain nerve cells (Fig. 15, 16). Numerous autonomic terminations have a wavy appearance (Fig. 17). A considerable number of myelinated nerve fibres are observed. In most cases they run through the muscularis layer to end in the propria, but in some cases they terminate freely in the internal sphincter. Myelinated nerve fibres generally consist in small- and medium-sized fibres, but sometimes, in large-sized fibres changing their size in their course (Fig. 18). They show the characteristic varicosities and are identical with the sensory nerves described by H. SETO.

3)   External sphincter:

The nerve fibres distributed in the external sphincter consist in myelinated and non-myelinated fibres.

Myelinated nerve bundles having small branches run through several muscle bundles to the effector muscle fibre, where they lose their myelin sheaths (Fig. 19, 20) and terminate in end-plates lying under the sarcolemma. The end-plates show the characteristic staining and refraction of light, and are easily distinguished from the surrounding muscular substances (Fig. 21, 22).

In the end-plate several fundamental and arborization nuclei are observed; the former have not degenerated and the latter have degenerated to the vanishing point with the degeneration of the end-plate. Thus, the arborization nuclei seem to originate from Schwann's cells. The nerve fibres in the end-plate ramify into several fine fibrils which terminate in the isotropous zone of the muscle fibrils forming a terminal and periterminal network. Therefore this isotropous zone is impregnated deeper than the surrounding tissues. This place must be identical with the myoneural junction in the physiological sense (Fig. 23, 24, 25).

Generally a nerve fibre forms only one end-plate but sometimes forms more than two end-plates (Fig. 26).

Non-myelinated fibres accompany myelinated fibres at first, then part from them and terminate either in the same end-plate or in an other simple end-plate, which Boeke has named "akzessorische (sympathische) Nervenfaser". According to the results of my experiments, these are very rare and neither fundamental nuclei nor periterminal networks are observed at their endings (Fig. 25, 27).

Besides these nerves, some myelinated fibres ramify into several branches and terminate freely in muscle fibres. They may be sensory nerves (Fig. 28, 29). Muscle spindles are also observed (Fig. 30, 31). They are encapsulated with connective tissue, in which myelinated fibres are changed into a spindle-shaped glomerular ending.

Kure described sympathetic, parasympathetic and extrapyramidal end-plates, but the author could not distinguish them from each other.

IV.   SYSTEMATIC OBSERVATIONS OF THE INNERVATION OF THE URETHRA AND THE SPHINCTERS OF THE URINARY BLADDER

The author examined the secondary degeneration of nerve fibres and end-plates after section of the roots of the spinal cord. Using adult male dogs as experimental animals, operations were performed as follows:

The spinal canal was opened under general anesthesia with sodium isomytal, and the dorsal and ventral roots were separated carefully from each other, and only the ventral or the dorsal roots were cut on both sides or on one side at a point distal to the spinal ganglia. In other animals the pudic nerves were cut on one side at their roots. Some specimens were removed for silver impregnation 3~4 days after the operation, and others for acid hematoxyline staining 5~6 days after the operation.

(1)　Section of the dorsal roots on both sides (L. 1⋯⋯L. 3)

A few degenerated myelinated nerve fibres were found in the propria of the urethra (Fig. 32). The myelin sheaths had been broken and looked like granules. In the sphincter muscles no degenerated nerve fibres were found.

(2)　Section of the dorsal roots on both sides (L. 4⋯⋯L. 7)

No degenerated nerve fibres were found anywhere.

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

Many degenerated myelinated nerve fibres were observed in all portions of the urethra, and especially in the propria and the epithelium almost all of the myelinated nerve fibres showed degeneration (Fig. 33, 34, 35).

In the external sphincter both myelin sheaths and axis-cylinders had degenerated (Fig. 36, 37)

(4)　Section of the dorsal roots on the right side (L. 1⋯⋯L. 3)

A few degenerated nerve fibres were found in the propria and the epithelium of the urethra of the right side, while on the left side no degenerated nerve fibres were observed.

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

Many degenerated nerve fibres were observable in the urethra and the sphincter muscles of the right side. On the left side some nerve fibres showed degeneration (Fig. 38), but far fewer than on the right side.

(6)　Section of the ventral roots on the right side (L. 1⋯⋯L. 3)

(7)　Section of the ventral roots on the right side (L. 4⋯⋯L. 7)

In both cases no degeneration of nerve fibres could be found in any portion of the urethra and sphincter muscles.

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

In the mucous and submucous layer of the urethra some degenerated nerve fibres were observed not only on the right side but also on the left side (Fig. 39). The number of degenerated nerve fibres was less than in the case of posterior rhizotomy.

The end-plates in the external sphincter showed degeneration: The nerve fibres were swollen, broken down and had the appearance of a granular string. The number of the nucleoli was rather increased in the fundamental nuclei. The fundamental nuclei had not degenerated, while the arborization nuclei had degenerated to the vanishing point (Fig. 40, 41, 42, 43). "Akzessorische Nervenfaser" (BOEKE) had also degenerated (Fig. 44).

(9)　Section of the right pudic nerve.

In all portions of the urethra of the right side many degenerated myelinated nerve fibres were observed in the mucous, submucous and muscular layer (Fig. 45). In the external sphincters many myelinated nerve fibres and end-plates showed degeneration (Fig. 46, 47). There were as many of these degenerated nerve fibres and end-plates as when both anterior and posterior roots (S. 1⋯⋯S. 3) were cut at the same time.

On the left side of the urethra and sphincter muscles and even in the fundus

of the bladder, a few nerve fibres showed degeneration (Fig. 48).

The results in the cases of nerve section on the left side were comparable.

V. DISCUSSION

In 1932 STOEHR Jr. and REISER described the peripheral pattern of the autonomic nerve system as a fine network, which they named "Terminalreticulum". Similarly, JABONERO (1953) described "norvöse Synzytium" considering that these network structures are always enclosed in a band of protoplasm. Both authors maintain that the fibres in these terminal structures never show a free ending and do not degenerate after section of the preganglionic or postganglionic fibres of the autonomic nerves.

H. SETO discovered thick nerve endings in many visceral organs, which terminate freely and could be easily differentiated from the autonomic nerves, and was convinced that these nerves should be considered sensory nerves.

OTSU of our laboratory has studied these sensory nerves and revealed the following facts:

(1) They are myelinated even near their endings.

(2) They have their

Table 1. Segmental innervation of the urethra and the sphincters of the bladder according to secondary degeneration after sectioning the nerve trunks at various levels

	Periods from section to extirpation	Bladder cervix		Prostatic Part		Membranous part		Internal sphincter		External sphincter	
		sectioned side	opposite side	sectioned side	opposite side	sectioned side	opposite side	sectioned side	opposite side	sectioned side	opposite side
bilat. post. rhiz. (L. 1, 2, 3)	5 days	+		+		+		+		+	
bilat. post. rhiz. (L. 4, 5, 6, 7)	5 days	−		−		−		−		−	
bilat. post. rhiz. (S. 1, 2, 3)	5 days	‡		‡		‡		‡		‡	
right post. rhiz. (L. 1, 2, 3)	5 days	+	−	+	−	+	−	+	−	+	−
right post. rhiz. (S. 1, 2, 3)	5 days	‡	+	‡	+	‡	+	‡	+	‡	+
right ant. rhiz. (L. 1, 2, 3)	5 days	−	−	−	−	−	−	−	−	−	−
right ant. rhiz. (L. 4, 5, 6, 7)	5 days	−	−	−	−	−	−	−	−	−	−
right ant. rhiz. (S. 1, 2, 3)	3, 4 & 5 days	‡	+	‡	+	‡	+	‡	+	‡	+
section of the r-pudic nerve	5 days	‡	+	‡	+	‡	+	‡	+	‡	+

Ehrlich's acid hematoxyline method — Ehrlich's a. h. & Bielschowsky's method

nerve cells in the spinal ganglia of the dorsal roots of the spinal cord; the postganglionic fibres have no interposing nerve cells till their terminations.

From this standpoint, if the spinal ganglia were resected operatively, the sensory nerves would degenerate. On the other hand, the autonomic nerves always have their nerve cells in their course to the effector tissues, and sectioning spinal ganglia would cause secondary degeneration only in preganglionic fibres, and not in postganglionic fibres beyond the interposing nerve cells. Degenerate nerve fibres observed in the mucous or submucous layers where there are no longer any preganglionic fibres, must, therefore, be sensory in nature.

According to these facts, OTUS was able to determine the source of the sensory nerves in the alimentary canal and named this method "Systematic observation of the visceral sensory nerves".

Using this method, many investigators of our clinic have found sensory nerves in various viscera: i. e. TANAKA in the esophagus, INOUE in the biliary tract, TSEI in the liver, MAKINO in the small intestine, LEE in the colon, WANG in the sigmoid and rectum, SATO in the ovary, OTSUJI in the testis, YOSHIDA in the urinary organs and CHENG in the large blood vesels.

Sensory nerves in the urethra were observed by OJIMA in the cat, by WATANABE, YAMADA and MORI in the female dog. They concluded that more intraepithelial fibres are observed in the urethra than in the bladder.

The author found few autonomic nerve cells and numerous well-developed autonomic networks in the urethra. A number of sensory nerves were observed in the mucous and submucous layer, and genital nerve corpuscles were found in the submucous layer of the urethra. In the internal sphincter sensory nerves showed arborized terminations. In the external sphincter muscle-spindles and sensory nerves with free endings were found. All of these sensory nerve fibres were myelinated.

My experiments were performed according to OTSU's method. After rhizotomy, most of the myelinated fibres observed in the mucous and submucous layers degenerated, which proved that these nerve fibres are sensory in nature and pass through the dorsal roots of the spinal cord.

G. WEDDELL emphasized that the terminal structure of sensory nerve endings were usually free-endings. But JABONERO maintained that sensory nerve endings have specific structures which tend to expand their terminal surface and STOEHR Jr. indicates that sensory nerve endings show a fine network resembling "vegetetive Terminalreticulum", when studied in detail. TE LIN TSEI of our laboratory, who studied the afferent nerves in the liver, maintains that some visceral sensory nerves, though they apparently seem to terminate in free endings, change sometimes into fine fibrils forming a network like the autonomic nerves, terminal expansions or special end apparati. The author found that some sensory nerves of the urethra showed terminal expansions in the ending, and considers that the free endings of the visceral sensory nerves must be more closely examined.

As for the motor nerve endings of the external sphincter, end-plates and "akzessorische Nervenfaser" (BOEKE) are observed, but an autonomic network can not

be proved.   In the internal sphincter, a nerve plexus and ganglia are found, but spinal motor nerve endings can not be observed anywhere.

Spinal moter nerve fibres have no interposing nerve cells till their cell-stations in the anterior horn of the spinal cord.   If the ventral roots of the spinal cord are cut, the peripheral motor nerve fibres must degenerate.

In this experiment, the ventral roots of S. 1······S. 3 and the pudic nerves were resected.   Specimens were taken from the external sphincter 3∽5 days after operation.   The end-plates showed degeneration in the specimens taken 3 days after the operation and were beginning to vanish after 5 days.   Thus it may be concluded that the degeneration of the end-plates reaches an optimal stage for observation on the 4 th day after the resection of ventral roots.

Since 1909 Boeke has been studying the end-plates of skeletal muscles, and maintains that skeletal muscles are innervated not only by spinal motor nerves but also by sympathetic nerves.   Aoyagi, Tsunoda and other investigators supported this theory from the histological standpoint.   Kure believed in the existence of spinal motor, sympathetic, parasympathetic and extrapyramidal end-plates, which he studied histologically and physico-chemically.   But Willson, Iwanaga, Kirita and Suzuki denied his opinions.

The author proved that the "akzessorische Nervenfasen" (Boeke) were only seldom observed and they originated in myelinated nerve fibres formed the end-plates, and showed degeneration following resection of the ventral roots of the spinal cord.   Therefore the author considers that these nerve fibres must be collateral fibres of the spinal motor nerves.   The existence of the autonomic or extrapyramidal innervation of the external sphincter can not be recognized histologically, though it seems to be a reasonable supposition.   This innervation may have a certain relation with the end-plates and the nerve fibres running along the capillaries adjacent to the end-plates.

The results of my histological experiments are as follows:

Sensory nerves of the urethra and the internal sphincter of the dog are derived from the dorsal roots of the spinal segments between L. 1······L. 3 and S. 1······S. 3. Both the sensory and the motor nerves of the external sphincter are derived from S. 1······S. 3.

Following section of the dorsal roots between L. 1······L. 3 on the right side, no degenerated nerve fibres were found in the urethra and the sphincters of the opposite side.

The resection of the ventral or dorsal roots between S. 1······S. 3 on the right side caused degeneration in the urethra and the sphincters mainly on their right sides and a few on their left sides.   Therefore the ventral roots must consist not only of motor nerves but also of some afferent nerves.

Yoshida of our laboratory has maintained that most of the afferent nerves of the bladder 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 and from the bilateral roots between

S. 1……S. 3. The results of the author's experiments on the urethra are the same.

Almost all myelinated nerve fibres distributed in the urethra and the sphincters show degeneration following section of both the ventral and dorsal roots of the sacral segments as well as of the pudic nerves. These nerve fibres must, therefore, be carried mostly by the pudic nerves.

VI. SUMMARY AND CONCLUSION

The nerve endings in the urethra and the sphincters of the urinary bladder of the male dog have been studied, and systematic observations of their innervation have been performed.

The results are summarized as follows:

1) Myelinated nerve fibres and sensory nerve endings are observed in the urethra and the sphincters of the urinary bladder.

2) Sensory nerve endings are unbranched or ramified terminations. Sometimes they form terminal expansions at their endings.

3) Sensory nerves are myelinated even near their terminations.

4) Genital nerve corpuscles are observed in the urethra and muscle-spindles in the external sphincter.

5) Spinal motor end-plates are found in the external sphincter.

6) "Akzessorische Nervenfasern" (BOEKE) are only seldom observed. They must be collateral fibres of motor nerve fibres.

7) Neither autonomic nor extrapyramidal innervation is demonstrable in the external sphincter.

8) Most of the sensory nerves of the urethra and the internal sphincter are derived from the dorsal roots of the homolateral side between L. 1……L. 3 and S. 1……S. 3, and a few from the dorsal roots of the opposite side between S. 1 ……S. 3.

9) Few of the afferent nerves of the urethra and the internal sphincter are derived from the ventral roots of both sides between S. 1……S. 3.

10) Most of the afferent and efferent nerve fibres of the sphincters of the urinary bladder are derived from S. 1……S. 3, and carried by the pudic nerve.

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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% neural formol solution. This solution should be made only by diluting the mother neutral formol with running water. This formol solution is then divided into 4 to 5 plates. And then the specimens are transferred one by one from the first plate to the 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 distilled 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 1 hours, in the darkness,
3) Washed with distilled water for a few seconds,
4) Put into ammonical silver solution until the specimens are colored light yellow,
5) Placed in 10% sodium-potassium tartrate solution for a few minutes until the specimens are 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 for a few minutes,
9) Placed in 20% sodium thiosulfate solution,
10) Washed in distilled water,
11) Dehydrated and mounted
    Abbreviations :
        B·········BIELSCHOWSKY's method
        E·········EHRLICH's method
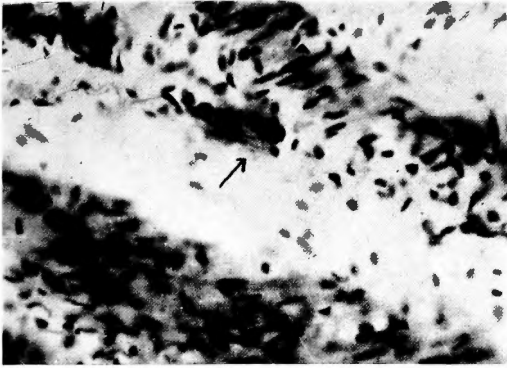
Fig. 1 Ganglion in the submucous layer of the urethral orifice. × 400 B.

Fig. 2 "Nervöse Synzytium" in the submucous layer of the urethral orifice × 400 B.
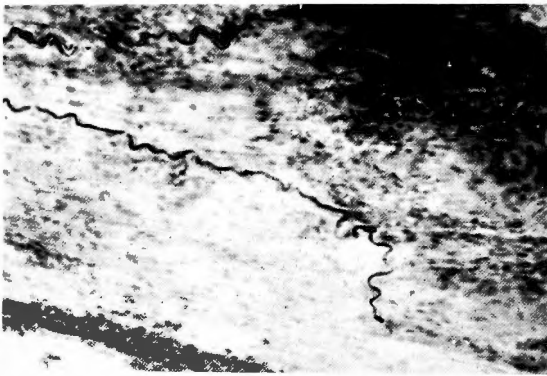
Fig. 3 Myelinated nerve fibres in the submucous layer of the pars prostatica × 200 E.
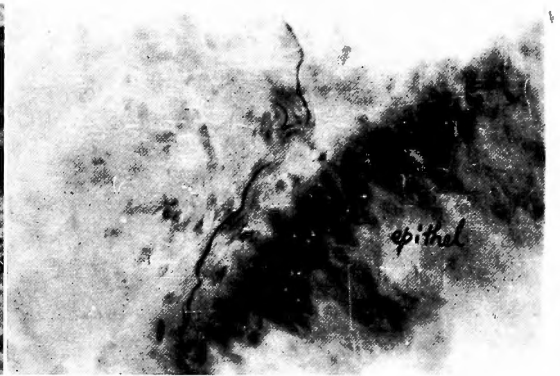
Fig. 4 Intraepithelial myelinated nerve fibre in the pars membranacea × 400 E.

Fig. 5 Intraepithelial myelinated nerve fibre in the pars prosatica × 200 E.
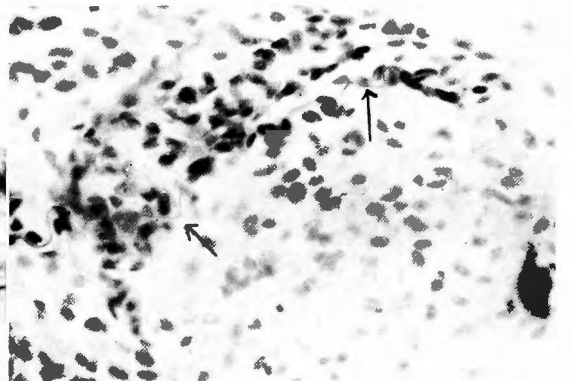
Fig. 6 Sensory nerve along a capillary in the submucous layer of the urethra × 400 B.
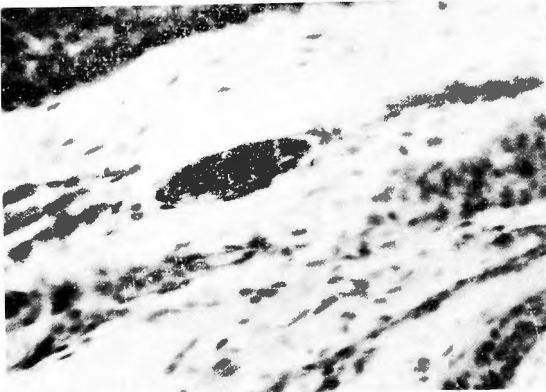
Fig. 7 Genital nerve corpuscle in the submucous layer of the pars prostatica × 400 B.
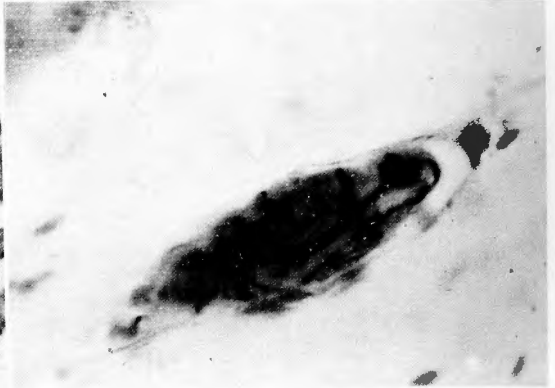
Fig. 8 The same preparation as Fig. 7. × 900 B.
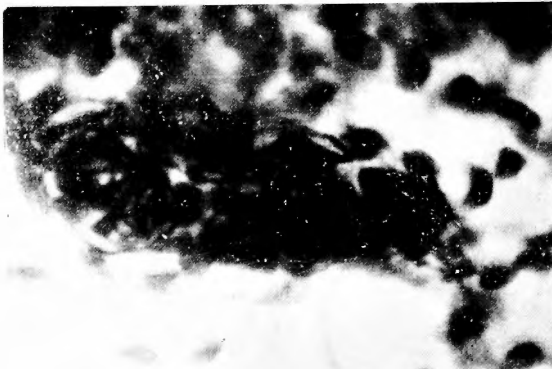
Fig. 9 Genital nerve corpuscle in the mucous layer of the urethral orifice × 400 B.
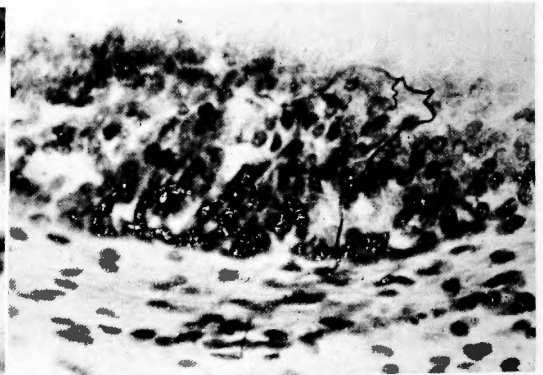
Fig. 10 Bifurcated sensory nerve in the epithelium of the pars membranacea × 400 B.
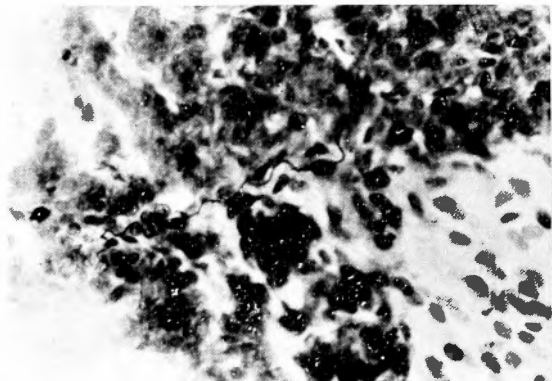
Fig. 11 Sensory nerve in the epithelium of the pars membranacea × 400 B.

Fig. 12 Sensory nerve ending forming a network structure. The same preparation as Fig. 11. × 900 B.
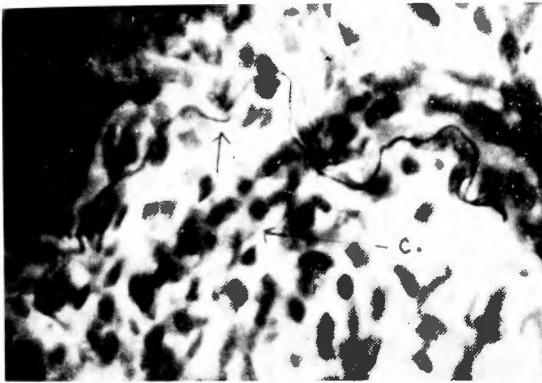
Fig. 13 Sensory nerve along a capillary in the ubmucous layer of the pars membranacea × 400 B.
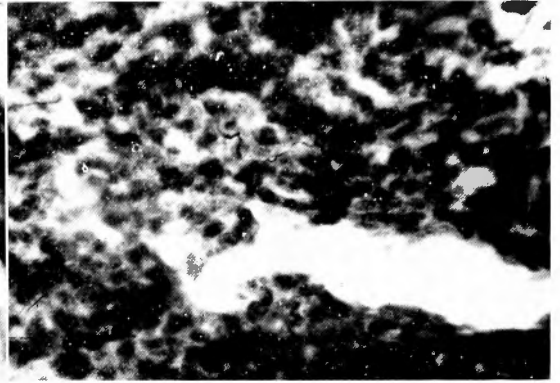
Fig. 14 Nerve fibre in the mucous layer of the pars prostatica × 400 B.
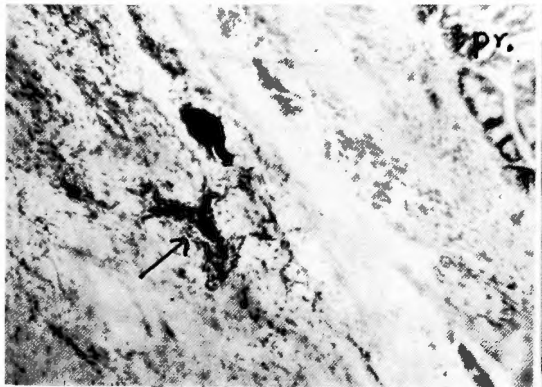
Fig. 15 Ganglion in the pars prostatica pr.··· prostate × 200 B.
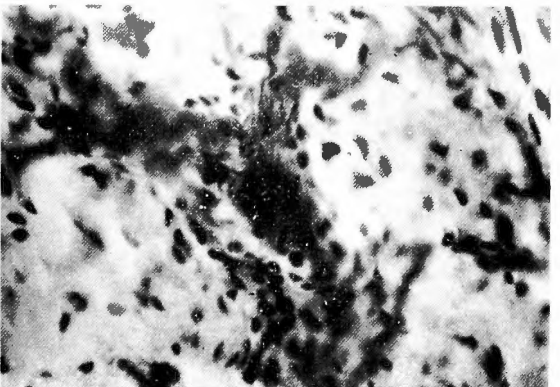
Fig. 16 The same preparation as Fig. 15. × 400 B.
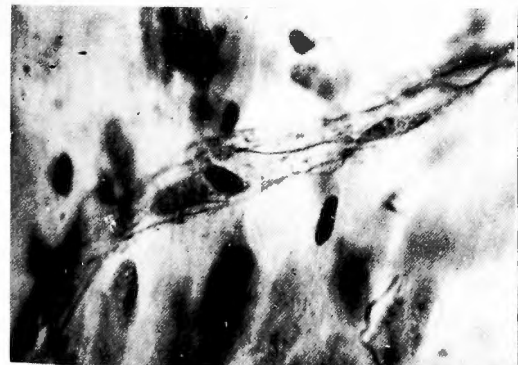
Fig. 17 "Terminalreticulum" in the internal sphincter (Human being) × 400 B.
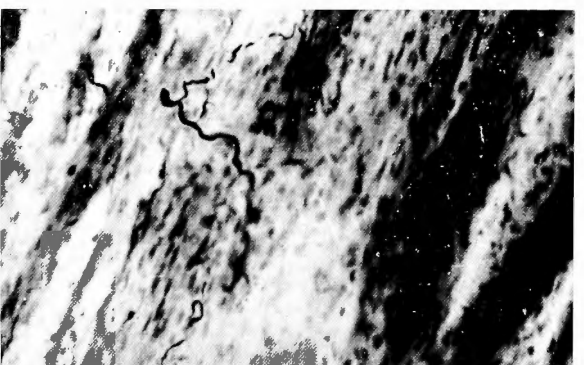
Fig. 18 Branched sensoory nerve in the internal sphincter × 200 B.
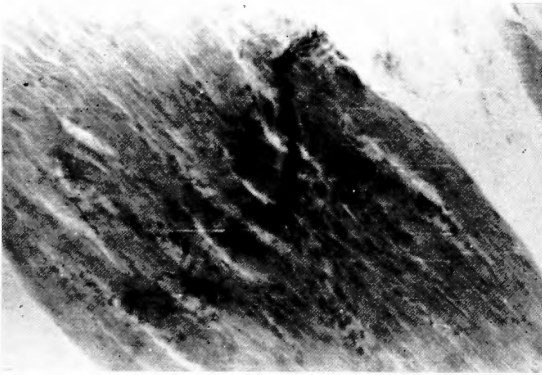
Fig. 19 Myelinated nerve fibres in the external sphincter × 200 E.
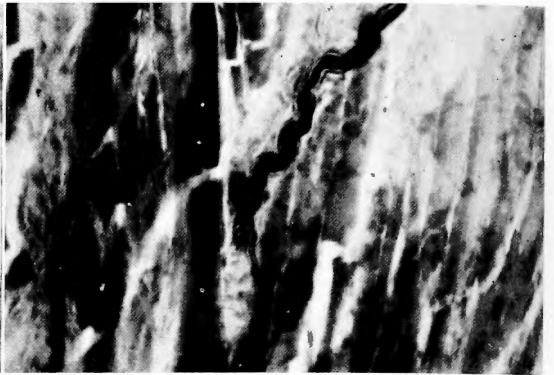
Fig. 20 Myelinated nerve fibres in the external sphincter × 200 E.
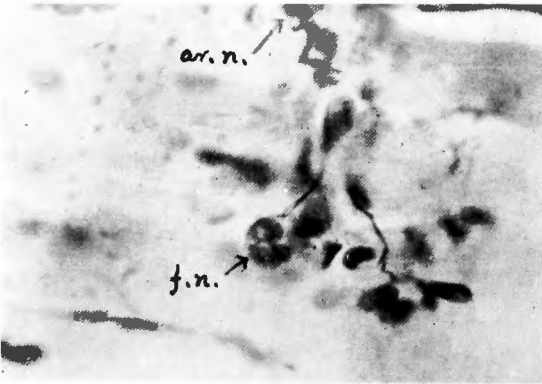
Fig. 21 Motor end-plate in the external sphincter ar. n.⋯⋯arborization nuclei f. n.⋯⋯ fundamental nuclei × 900 B.
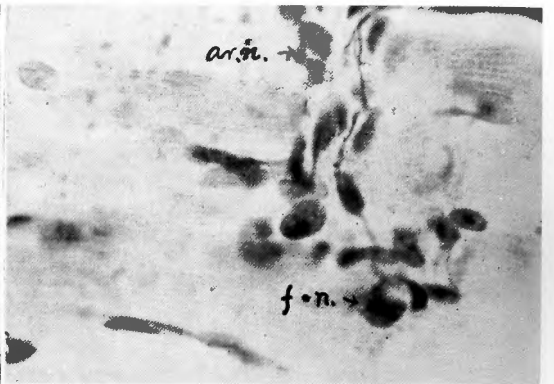
Fig. 22 The same preparation as Fig. 21. × 900 B.
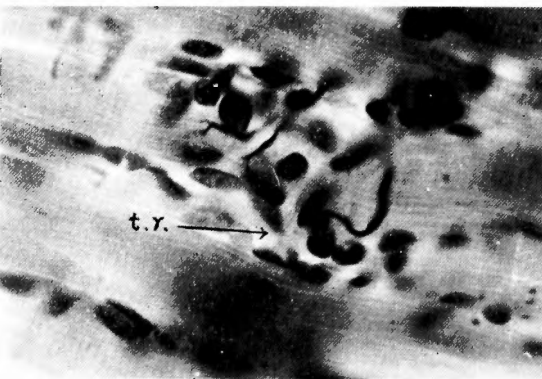
Fig. 23 Motor end-plate in the external sphincter t. r.⋯⋯⋯periterminal network × 900 B.
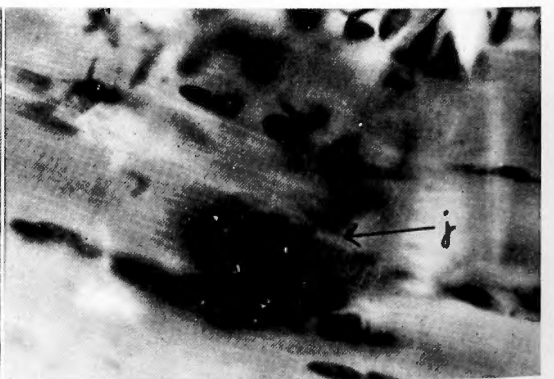
Fig. 24 The same preparation as Fig. 23. Showing myoneural junction (j). × 900 B
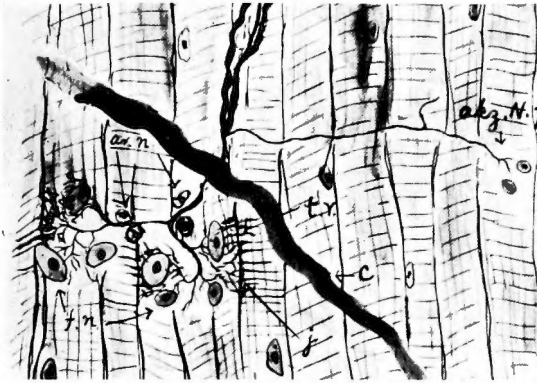
Fig. 25 Motor end-plate (Drawing) akz. N. f.
...... „Akzessorische Nervenfaser" × 900
B.
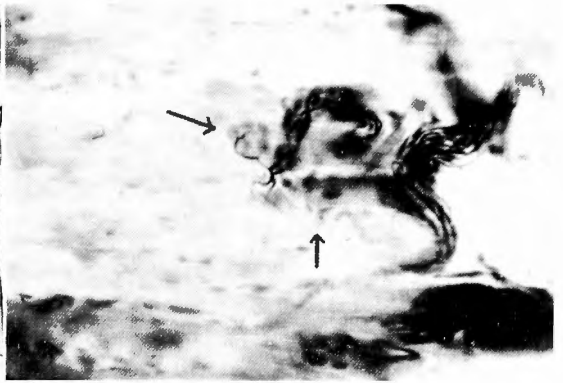
Fig. 26 A nerve fibre forming two end-plates
× 400 B.

Fig. 27 "Akzessorische Nervenfasern" in the
external sphincter × 400 B.
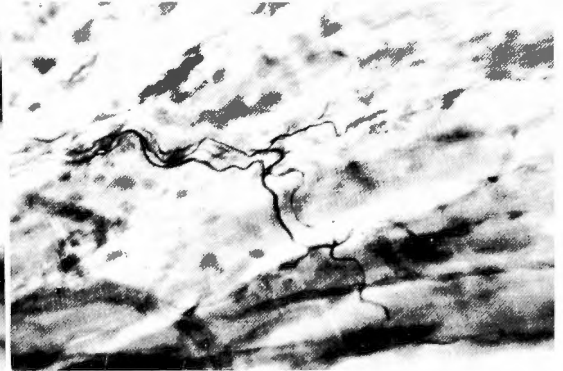
Fig. 28 Sensory nerve fibres in the external
sphincter × 400 B.
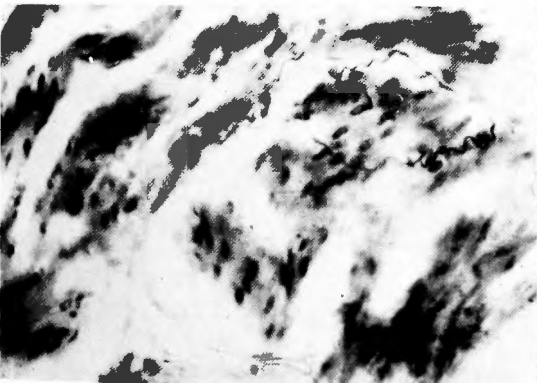
Fig. 29 Sensory nerve fibres in the external
sphincter × 400 B.
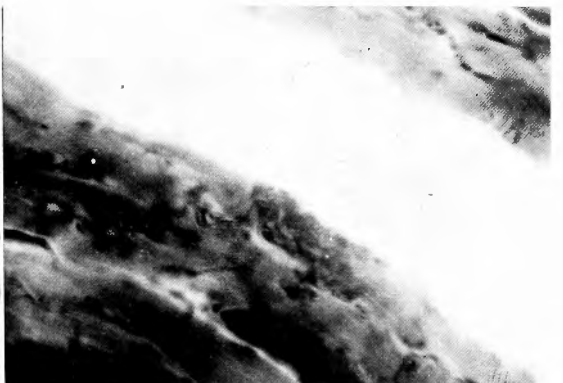
Fig. 30 Muscle-spindle in the external sphincter
× 400 B.
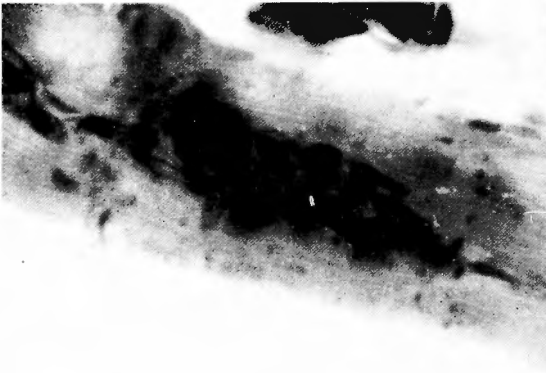
Fig. 31 Muscle-spindle in the external sphincter ×400 B.
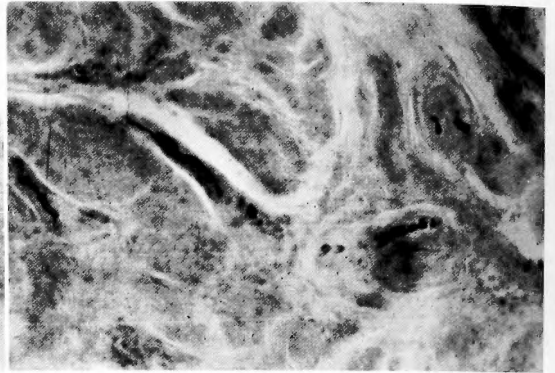
Fig. 32 A degenerated nerve fibre in the submucous layer of the urethra 5 days after post. rhiz. on both sides (L. 1……L. 3) ×200 E.
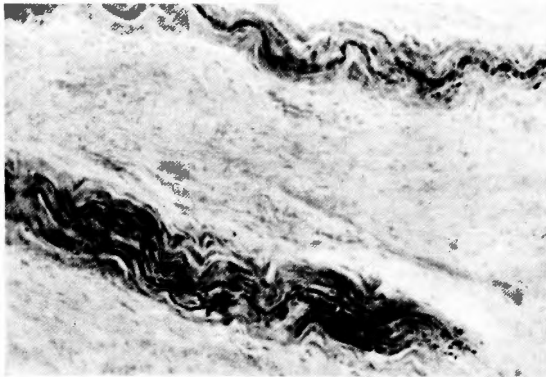
Fig. 33 Degenerated nerve fibres in the submucous layer 5 days after post. rhiz. on both sides (S. 1……S. 3) ×200 E.
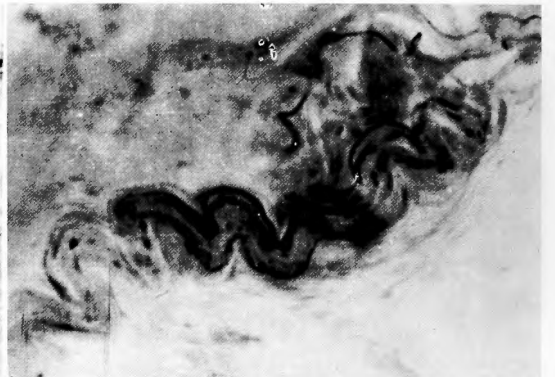
Fig. 34 Degenerated nerve fibres in the internal sphincter 5 days after post. rhiz. on both sides (S. 1……S. 3) ×400 E.
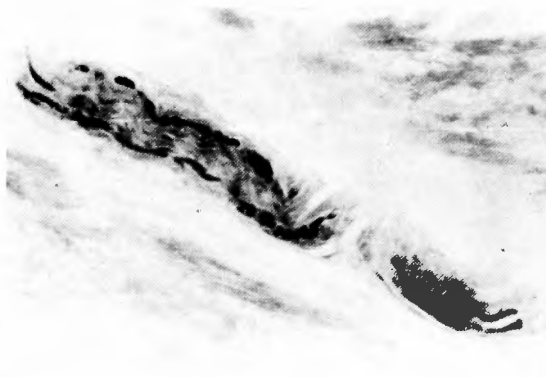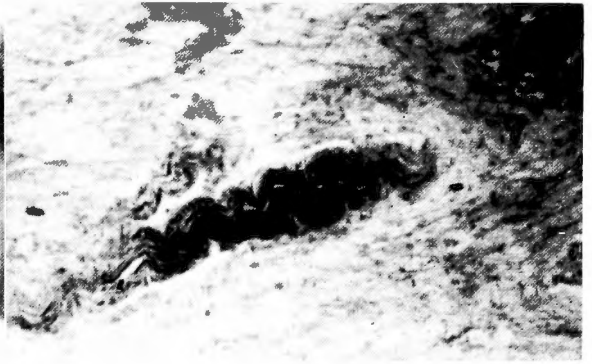

Fig. 35 Degenerated nerve fibres in the submucous layer 5 days after post. rhiz. on both sides (S. 1……S. 3) ×200 E.
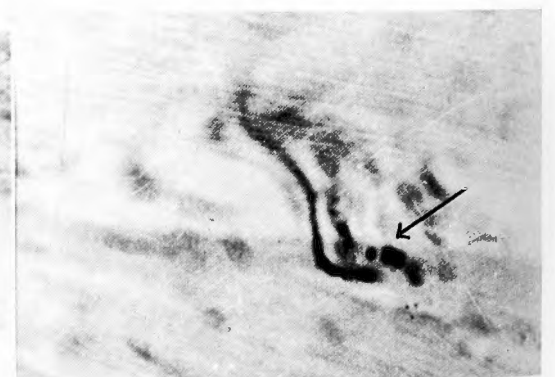
Fig. 36 Degenerated nerve fibres in the external sphincter 5 days after post. rhiz. on both sides (S. 1……S. 3) ×200 E.
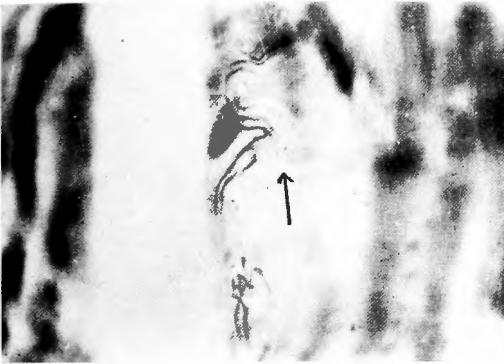
Fig. 37 A degenerated nerve fibre in the external sphincter 3 days after post. rhiz. on both sides (S. 1⋯⋯S. 3) × 400 B.

Fig. 38 Degenerated nerve fibres in the mucous layer of the opposite side 5 days after rt. post. rhiz. (S. 1⋯⋯S. 3) × 200 E.
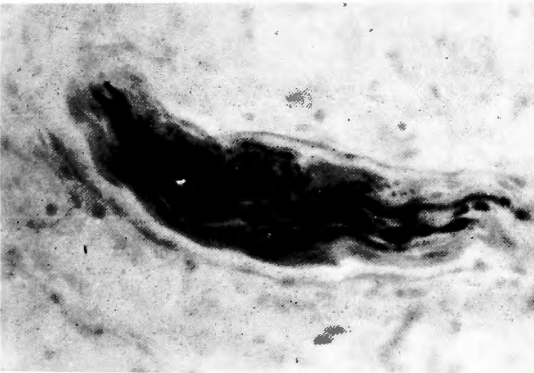
Fig. 39 Degenerated nerve fibres in the mucous layer of the opposite side 5 days after rt. ant. rhiz. (S. 1⋯⋯S. 3) × 400 E.

Fig. 40 Degenerated nerve fibres in the external sphincter 3 days after ant. rhiz. on both sides (S. 1⋯⋯S. 3) × 900 B.
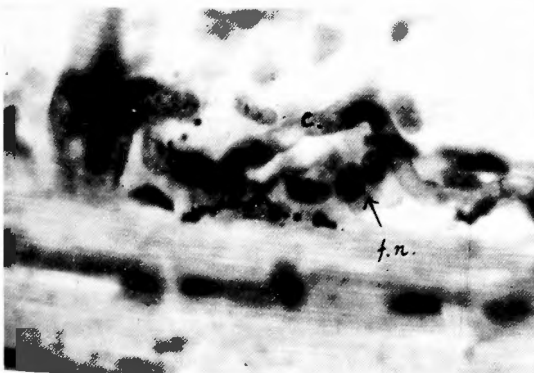
Fig. 41 A degenerated end-plate in the external sphincter 4 days after ant. rhiz. on both sides (S. 1⋯⋯S. 3) c⋯⋯capillary × 900 B.
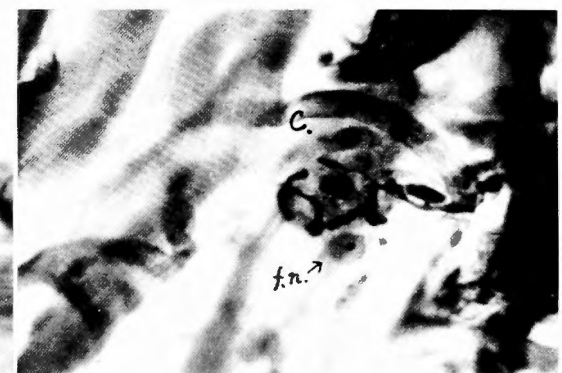
Fig. 42 A degenerated end-plate in the extenal sphincter 3 days after ant. rhiz. on both sides (S. 1⋯⋯S. 3) × 900 B.
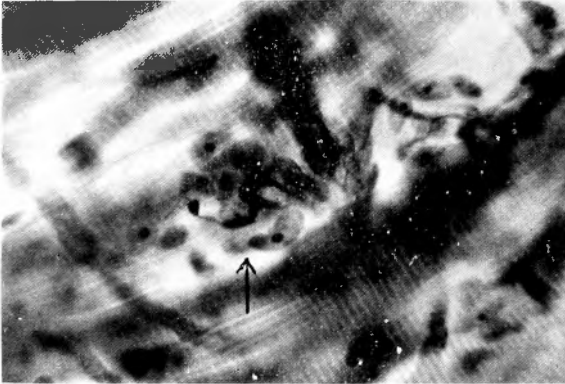
Fig. 43 A degenerated end-plate in the external
sphincter 4 days after ant. rhiz. on both
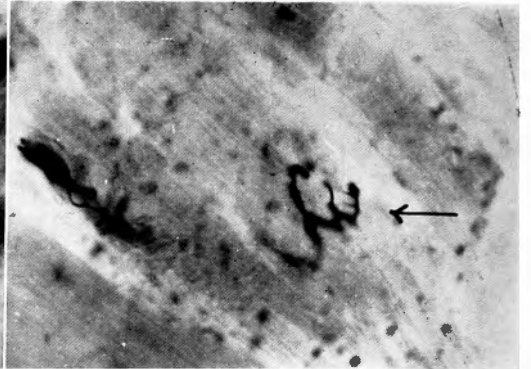sides (S. 1……S. 3) × 900 B.

Fig. 44 A degenerated "akzessorische Nervenf-
aser" 5 days after ant. rhiz. on both
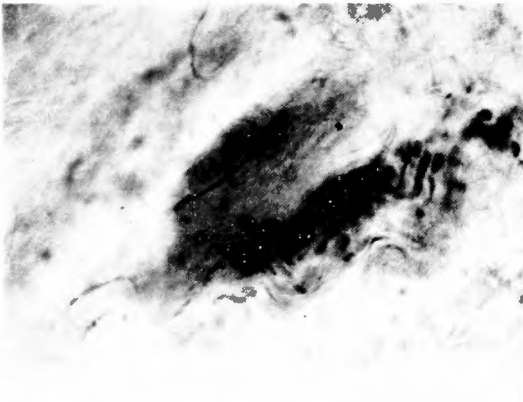sides (S. 1……S. 3) × 900 B.

Fig. 45 Degenerated nerve fibres in the subm-
ucous layer of the pars prostatica 5 days
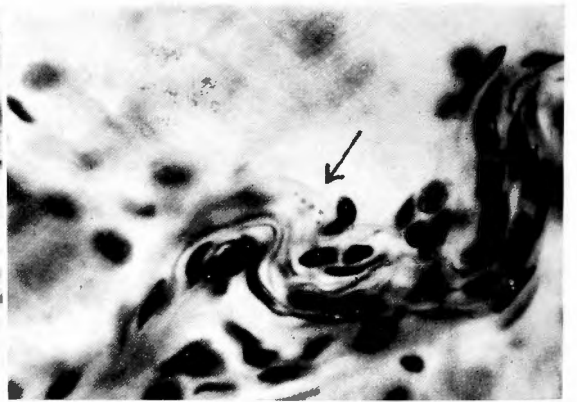after section of pudic nerve × 400 E.

Fig. 46 A degenerated nerve fibre in the exte-
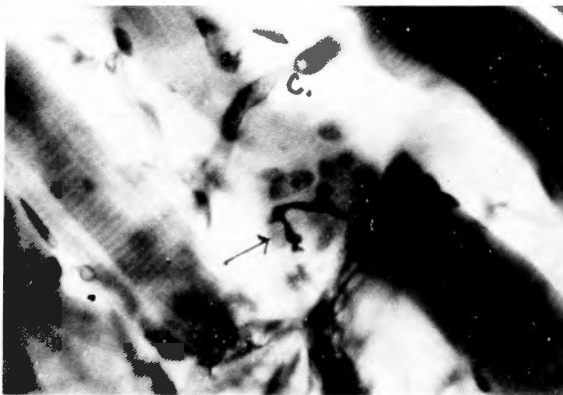rnal sphincter 3 days after section of
pudic nerve × 900 B.

Fig. 47 A degenerated end-plate in the exter-
nal sphincter 4 days after section of
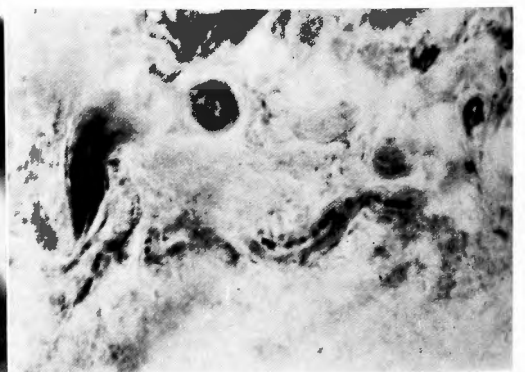pudic nerve × 900 B.

Fig. 48 A degenerated nerve fibre in the muc-
ous layer of pars membr. of the opposite
side 5 days after section of rt. pudic n.
× 400 E.

和 文 抄 録

犬尿道及び膀胱括約筋の神経支配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 武 田 温 雄

BIELSCHOWSKY 氏神経鍍銀法の瀬戸氏変法，鈴木氏変法及び EHRLICH 氏髄鞘染色法を用いて，犬の尿道及び膀胱括約筋の知覚神経並びに運動神経の末梢像及び分布状態を検索し，更に腰仙髄前根，後根並びに陰部神経を両側或は偏側に於て実験的に切断した犬に於て，尿道，膀胱括約筋組織内の末梢神経の二次的変性像を追求し，之等の結果から，尿道，膀胱括約筋の知覚神経支配及び膀胱括約筋の運動神経支配に関して次の結果を得た．

1) 尿道及び膀胱括約筋に於て，有髄神経及び知覚神経を認めた．

2) 知覚神経終末は単独性或は単純分枝性に遊離端を以て終るものが多いが，中には先端に於て網状を呈するものも認められた．

3) 知覚神経は末梢近くまで有髄性である．

4) 知覚神経小体として，尿道に於て陰部神経小体を，外膀胱括約筋に於て筋紡錘を認めた．

5) 外膀胱括約筋に於て運動性終板を認めた．

6) 副行神経（BOEKE）は，極く少数しか認められない．而も仙髄前根を切断すると変性を来すので運動神経の副枝ではないかと考えられる．

7) 外括約筋の自律神経性支配，錐体外路性支配を組織学的に明らかにすることは出来なかつた．

8) 尿道及び内膀胱括約筋の知覚神経は大部分同側の S. 1〜S. 3の後根を通るが，一部は反対側の S. 1〜S. 3の後根を通るものもある．

9) 尿道及び内膀胱括約筋の知覚神経の一部は，同側及び反対側の S. 1〜S. 3の前根を通る．

10) 尿道及び膀胱括約筋の求心性並に遠心性神経の大部分は S. 1〜S. 3に由来し，而も殆んど陰部神経を介して分布している．