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The Problems of Abdominal Pain

From the Second Surgical Clinic, Kyoto University Medical School
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by
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I. Physiological Observations

by KAZUAKI OBA, YUTAKA WATANABE, NOBORU KIMURA, YASUSHIGE KATSUTA, HIROSHI OKAWA, YUTAKA YOHIIKE, MASAO YAMAMURA.

ACETYLCHOLINE METHOD (KIMURA, OBA)

We have discovered that 0.5 to 1.0 c.c. of 2.5 to 5.0% acetylcholine solution, injected into viscera, causes visceral sensations. Therefore we will call this method "Acetylcholine (A.C.) Method."*

fig. 1

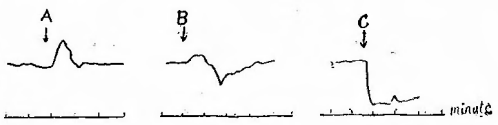


fig. 2

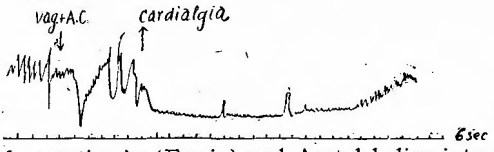


Fig. 1. Change of blood pressure by the injection of vagostigmin (Eserin) and Acetylcholine into the small intestines of rabbits.

A: Vag. & A. C. were applied on the intestines, B.P. increased for a few minutes and then decreased.

B: Vag. & A. C. were injected into the wall of the intestines. B. P. showed a slight increase and then decreased

C: Systemic injection of Vag. & A. C. reduced the B. P. without increase. Increased B. P. indicates the existence of pain.

Fig. 2. Vag. & A. C. were injected into the cecum of a man.

A kymogramm of the movement of the ileum was recorded at a point 60 cm above the cecum. Peristalsis and tonus of the ileum were completely inhibited due to the occurence of cardialgia.

We succeeded in arousing visceral sensations in 55% of our 365 laparotomy clinical cases. Our method was successful not only in such muscular organs as alimentary canals, urinary bladders and uteruses but also in such parenchymatous ones as kidneys, pancreases and ovaries.

1. VISCERAL SENSATIONS OF THE ALIMENTARY CANAL.

As MACKENZIE has described, the sites of pain originating in various parts of the alimentary canal were always felt close to the median line of the trunk front or back. However, on the two following points our results were not identical with his: (1) In our cases local signs of visceral pain from one portion of the viscus and those from neighboring portions gave broad overlapping areas on the abdominal surface; (2) In our cases the

*As to the critical studies on the A. C. method, Y. WATANABE and Y. YOSHIIKE will later report in detail on this journal.

pain was a little to the left of the median line below the navel.

The locating of these overlapping areas proves without a doubt that every part of the alimentary canal is innervated by the sensory fibers of two or more segments of the spinal cord. On the other hand, the results of our investigations on both humans and animals suggest that every part of the alimentary canal accepts the sensory fibers from the posterior roots on both sides of the spinal cord. RAY, BRONSON and NEIL found an interesting phenomenon that after unilateral interruption of the sympathetic trunks, there appears contralateralisation of the sites of visceral pain from the alimentary canal. However, they gave no explanation for this. We confirmed the existence of this phenomenon not only in visceral sensations but also in sensations of the somatic regions. We found that when the abdominal wall together with the sensory nerves was dissected on one side for the purpose of laparotomy, local signs of pressure on the median line of the abdominal surface were also contralateralised. (Fig. 3.) From this point of view, the consciousness of the local sign generally depends not only on the discriminative ability of a sensory nerve but also on the integration of sensations transmitted by two or more afferents. The RAY and NEIL contralateralisation is attributed to the dysfunction of this integration. The integration of the sensory impulses serve as the judgement of the site of the starting point rather than the relative situation of two or more points. Therefore we call it the "initial local sign." Thus our experiments have made clear the significance of the RAY-NEIL phenomenon.

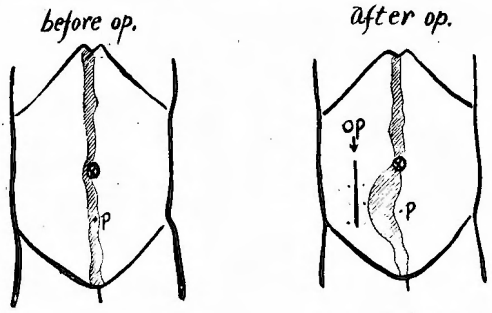


Fig. 3. Within the shadowed area finger pressure is felt by the patient as a stimulus on the median line of the abdomen. Point P on the median line is felt on the left side after a laporatomy on the right side.

Adequate stimulus, given to the various parts of the alimentary canal, resulted in referred pain at the proper regions of the abdomen while violent sudden pain made local signs of sensation rather obscure. In these cases patients always reported that the pain covered the whole abdomen. It was worth noting that the pain represented many visceral sensations including pressure and that the pressure sensation always preceeded the pain. Viscero-motor reflex(défense musculaire), resulting from stimulation of the alimentary canal, appeared in the same region of the local sign of the pain, that is, in an area spreading from the median line to both sides of the abdomen. The extent of the reflex contraction of the rectus abdominis muscle depends on the intensity and the position of the stimulus given to the alimentary canal. For instance, a violent stimulus, occuring suddenly, results in

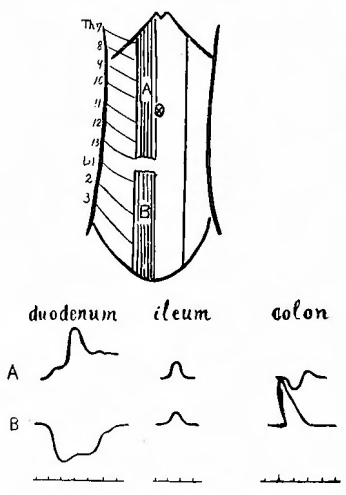


Fig. 4. A & B indicate the two lobes of the rectus abdominis muscle which are cut on the plane between T_{13} & L_1 nerves. The smaller stimulus given on the duodenum causes a contraction of the A muscle lobe and relaxation of B. The same stimulus on the ileum causes a contraction of both muscle lobes, while stimulus of the colon produces a relaxation of A with a contraction of B. Thus we can determine that the sensory innervation of the ileum occurs at least in the spinal segment $T_{13}-L_1$, (cat.)

the contraction of the entire muscle, while a smaller stimulus is followed by partial contraction of the muscle with the relaxation of the remaining portions (Fig. 4.). Y. WATANABE availing himself of this fact, physiogically determined what segments of the spinal cord supplied the sensory nerves to which parts of the alimentary canal. His results coincided with the patterns of the site of the visceral pain. The local sign of the viscero-sensory or viscero-motor reflex liberated from the alimentary canal always appeared along the median line of the abdominal surface, from upper parts of the viscus on the upper abdomen while from lower parts of the viscus on the lower abdomen. Therefore it did not suggest what region of the abdomen was actually stimulated but it roughly indicated what part of the whole length of the alimentary canal had been stimulated.

a. Gastric ulcers which, during laparotomy, did not respond to mechanical stimuli caused intense pain by the acetylcholine solution injected into the ulcers themselves. Five to ten minutes after the injection, when the pain had already gone, the ulcers themselves, but not the surrounding areas, were sensitive to finger pressure or rubbing with gauze. In relation to KARUTA's findings, it is an interesting fact that in cases of gastric ulcers, the blood which was cholinergic before operation, during and after laparotomy, changed noticeably to adrenergic. The adrenalinemia during laparotomy seemed, therefore, to blunt the sensitivity of the gastric ulcer while local increase of acetylcholine made it sensitive again.

b. Pain, originating in the appendix, when slight, was felt around the naval but when it became more severe the patient tended to refer it to the epigastrium. A lightly inflamed appendix was more sensitive to acetylcholine than a gangrenous, chronic or recurrent one. Therefore in reoccurences of appendicitis, the degree of the gastric syndrome which represents the sensitivity of the appendix itself, must therefore be lessened.

c. The stimulation of pylorus, duodenum, gall duct and appendix by A. C. produced almost the same pain as cardialgia. This was sometimes followed by nausea and vomiting.

d. We observed visceral sensations in three pancreas cases and had the following results: one patient felt no pain by the A. C. injection into the head of the pancreas; two patients were examined at the median portion of the viscus and both felt severe pain in the back, - one at the point of Boas and the other in a zonal region extending from the point of BOAS to both sides.

2. VISCERAL SENSATION OF THE UROGENITAL ORGANS.

The impulses of visceral pain from urogenital organs are believed to enter the spinal cord between the ninth thoracic and fourth sacral segment, but because of the lack of white rami between the second lumbar and the second sacral segment, those afferents are classified into two groups, i. e. the thoraco-lumbar (sympathetic) and the sacral (parasympathetic) pathways. Sensations transmitted by sacral sensory nerves are characteristic in that they cause desire to excrete.

In our study of sensations of the urogenital organs we used two method —electric stimulation as well as our A. C. method. These investigations were made during laparotomies under local or spinal anaesthesia. We had three factors to consider:

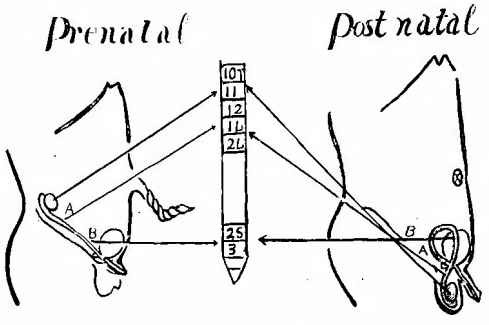
1. The existence of characteristics peculiar to sacral sensory nerves
2. The site of referred pain
3. Diminishment or disappearance of visceral sensation or its referred pain after anesthesia of certain spinal segments.

Generally speaking we found that most parts of these organs are under dual sensory innervation between the thoraco-lumbar and the sacral nerves and the visceral sensation on some parts of these organs are represented usually by the predominant side of the two. Pain in the ureter, for instance, on a part 10 cm lower than the pelvix of the kidney was always accompanied by a slight desire for micturition suggesting that the ureter accepts sacral sensory nervous supply far more extensively than has been as yet described. On the other hand, the sensation of micturition completely disappeared after the sacral anesthesia, Lut there still existed a sensation of pain which was referred to the side of the abdomen. Most parts of the ureter are therefore, under dual sensory innervation and the lower the

part, the more definite is the predominance of the sacral sensation.

The same can be said in regard to the spermatic cord. The visceral sensation of the spermatic cord from the epididymis to the external ring produced the referred pain on the supra-inguinal region while in the portion between the external ring and prostate gland the pain of the viscus referred to the penis or to the perineum. Therefore, at the former, the thoracolumbar sensory nervous supply seemed to be predominant, while at the latter, the sacral one. From birth on through life, the scrotal portion of a spermatic cord stands lower than the portion in the external ring or in its neighborhood. Nevertheless, the former accepts the sensory nerves from higher segments of the spinal cord than the latter. Post-natal, the sensory nervous supply of the spermatic cord seems, therefore, to be in inverse relationship to the site of the viscus. Keeping in mind the ontogenetic process of descensus testis, this apparent contradiction is well understood. (Fig. 5.)

Fig. 5.



3. The Sensation of the Testicle and the Ovary.

The human testicle is an organ easily available for study of visceral sensations. The contusions at the scrotum cause pain with a feeling of temporary collapse and also a deep sensation as if the testicle was getting into the abdomen. The first feeling disappears after spinal anesethesia of the sacral segments while the second does after anesthesia of the thoraco-lumbar segments. Thus we have analyzed two testicular sensations.

From the ontogenetic point of view the ovary is an organ analogous to the testicle. Consistently in our cases pain resulted from A. C. injection into the ovary. The site of the pain was in the suprainguinal region or in the loin just as the abdominal reference of the testicular pain. In 13 clincial cases A. C. was injected into the parenchym of the ovary and in nine cases pain was felt. The nature of the ovarian pain was very suggestive, i. e. patients complained of the pain "as if it were the pain of labour." These answers were very interesting to us. Then to examine the problem, Y. Yoshiike studied cats not long before parturition. However, in spite of the presence of nocireactions after the A. C. injection into the ovary, contraction of uterus muscles never appeared. Probably the patient complained of pain like labour pain because the site of the referred pain in the loin from the ovary bore some resemalance to pain at the beginning of labour.

4. Viscero-visceral Reflex.

The kidney accepts exclusively the thoraco-lumbar sensory fibers and a painful stimulus on the viscus referred to the side of the epigastrium or to the loin.

A 40-year-old male who had been suffering from the syndrome of gastric ulcer with symptoms such as cardialgia, black stool and vomiting was relieved by removal of the tuberculous calculous pyonephritis on the left side. We examined by retrograde pyelography a 22-year-old female who could not stand for more than half an hour on account of cardialgia,nausea and vomiting. We found that when both renal pelvexes were full of moljodol, she suffered exactly the same severe pain on the left side of the epigastrium as she had suffered before. Therefore we performed renal decapsulation of the left kidney. The patient recovered.

This syndrome should be called "reno-gastric syndrome."

The site of the pain resulting from A. C. stimulation of the uterus indicated something

different from descriptions in books. In addition to the pain in the suprapubic region, cardialgia with nausea often followed. The nausea caused by stimulation of the uterus may possibly explain the reflex hyperemesis in pregnancy, but it might be partly due to the vagomimetic stimulus by the A. C. absorbed into the blood.

A 22-year-old female who began to suffer from cardialgia vomiting and an irritable colon at the beginning of pregnancy was relieved by the presacral sympathectomy (Cotte and Meigs).

This suggests the existence of the utero-gastric and utero-colic reflex via hypogastric plexus.

A man on whom vasectomy was performed because of leprosy felt nausea when retropubic portion of the spermatic cord was tracted during the operation.

In our clinic WATANABE found, in his experiments on cats, that vomiting was caused by stimulation at any part of the abdominal viscera when a subcutaneous injection of acetylcholine or physostigmine had been given. Especially in the vagotonic state, the utero-gastric or the reno-gastric syndrome must, therefore, be brought into existence as viscero-visceral reflexes. This is true in regard to Aschner's reflex which is principally carried by a sensory trigeminal nerve. N. KIMURA clearly demonstrated in his experiments on rabbits that the reaction of ASCHNER'S reflex could affect the sympathetic as well as the parasympathetic nervous system. He did this by giving a preliminary stimulus to the sympathetic or the parasympathetic region of the hypothalamus.

5. SPINAL ANESTHESIA AS A METHOD OF TREATMENT FOR THE DYNAMIC STENOSIS OF THE ALIMENTARY CANAL.

As is well known, the syndrome such as the ileus often takes place as the result of long time spastic contractions at a certain part of the bowels and when the peristalsis of the bowels is generally somewhat inhibited, as if paralyzed. A painful stimulus given any place on the body inhibites the movement and the tone of the alimentary canal. Using the A C. method, Y. WATANABE demonstrated that pain, even in the case of colic of the bowels, reflexly inhibits peristalsis and the tonus of the remaining parts of the bowels (fig.1 fig.2). This reflex is liberated from the autonomic centre of the medulla oblongata or its neighborhood, because it, as Y. YOSHIIKE demonstrated, disappeared after transsection between the C2-C3 segments of the spinal cord. The mechanism of the ileus-syndrome by the spasm of the bowels is not therefore, due only to the spasm itself, but also to the peristaltic and tonic inhibition of the other parts which is caused by the colic.

A 20-year-old female who had been suffering from meteorism, colic pain and sometimes from ileus syndrome, was relieved by posterior rhizotomy between the 9Th-12Th segments. A 40-year-old male who, for a year after gastric resection for a gastric ulcer, suffered from the so called "dumping syndorome" got well when treated by alcohol anesthesia at the posterior roots of the lower thoracic segments.

These cases tell us that extraordinary impulses conveyed by the visceral afferent nerves can cause excessive sympathetic activity which in turn plays a part in the mechanism of spastic constipation, meteorism and the dynamic ileus. By a single induction of spinal anesthesia STABINS, TELFORD & SIMMIONS treated several cases of megacolon with excellent results. Availing ourselves of this method, we succeeded in the treatment of meteorism and of constipation which occurred after appendicectomies. It is conceivable that in these cases sensory blockages must have played a role which caused inhibition of excessive sympathetic activity.

6. THE HUMORAL ACTIVE SUBSTANCES IN THE BLOOD.

As MUSSER & GRIMM have already reported, adrenergic and cholinergic nature of blood does not necessarily represent sympaticotony and parasympaticotony. This is due probably to the reflex function of the adrenal gland, i. e. the adrenalin secretion from the adrenal medulla easily reacts not only to painful sensations but also to the choline like substance increased in the blood and often changes the nature to adrenergic. This is because the adrenal medulla is innervated by the cholinergic nerve.

By sensitisation with horse serum M. YAMAMURA obesrved the nature of rabbit's blood in anaphylactic shock. He found a remarkable tendency of the blood to decline to adrenergic during shock whereas terrible spasm of bronchus and intestines accompanied the shock.

7. OBSERVATIONS ON THE RADIATION OF VISCERAL PAIN TO THE LEGS. (Fig. 6a & b)

Pain of the abdominal viscera, especially of the urogenital organs, radiates sometimes to the legs but our clinical investigations using the A. C. method were not successful in the demonstration of this fact. In order to pursue the problem further, we studied the effects of electric stimulation of the sympathetic trunk which is considered the main pathway of the visceral sensory fibers. We cut off certain portion of the sympathetic trunk and the central end was stimulated by the induction current. We experimented on three cases and during the sympathectomies we stimulated between Th3 and Th4 ganglion but there was no radiation of the pain to the arms We performed the same experiments on four cases of Raynaud's disease in the foot and we stimulated the segments between the L3 and L4 ganglions. Two patients reported that they felt pain at the front and median regions of the thigh of the stimulated side. Even in these sucessful cases, the pain, however violent it was, did not extend beyond the median portion of the thigh. This is probably because of the lack of the white rami between L2-S2 segments of the spinal cord. The spinal nerves of the legs, motor or sensory, belong to the same segments between 2L-2S so that if the visceral sensory impulses are transferred to the spinal nerve originating in the same segment, they must be free from viscerogenic reflexes. In these spinal segments, however, the upper and the lower limits (L2 & S2) still receive some of the visceral sensory nerves which are, therefore, able to cause the referred pain at the correspondin, areas of the legs. In the innervation of the spinal nerves the front and median regions of the thigh belong to L1 and L2, so that only this area can be influenced by the visceral sensory impulses via the lumbar segments. On the posterior side of the legs the area which belongs to S2 is along the course of the trunk of the sciatic nerve. This area is therefore under the influence of those visceral sensations via the sacral nerves. Almost the same thin s might be said in regard to the défense musculaire of the legs.

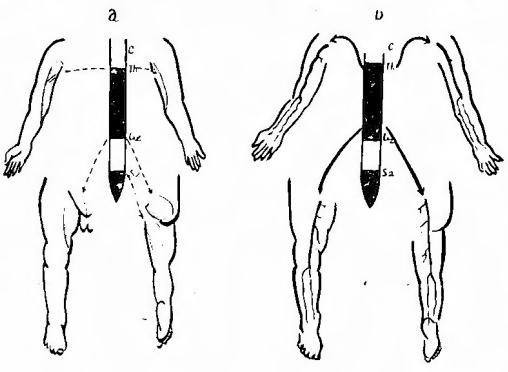


Fig. 6.

a) Radiation of visceral pain to the extremities via the spinal nerves. In this case radiation of pain cannot extend over limited areas (shadowed) because of the lack of white rami between the visceral afferent and the animal efferent nerves of the extremities.

b) Radiation of visceral pain to the extremities via the sympathetic nerves. In this case radiation is always able to extend to the end of the extremities because of the existence of white rami between the visceral afferents and the sympathetic nerves of the extremities.

These anatomical and physiological facts together with our results, make clear that the animal functions of the legs are, to a certain extent, independent of the visceral reflex. The same is true in regard to the arms because the spinal nerves there start or enter the spinal cord between C5-Th2 segments, but the existence of the white rami is not demonstrated within the scope of the cervical segments so that the visceral afferent fibers from the thoracic organs can fall in with the spinal nerves of the arms only between Th1-Th2 segments and within these segments only the pain is able to radiate to the corresponding areas of hands, i. e. to

the ulnar region. WEISS, POLLOCK and DAVIS illustrated the mechanism of the transmission of visceral sensory impulses to referred pain, analyzing it into three processes, the first to visceral afferent, the second to a somatic or a sympathetc efferent and finally to somatic or a proprioceptive afferent course. But there was no sign that sympathetic efferents play roles in the mechanism of the radiation of visceral pain, because, if it were so, the pain would have been likely to appear at the end of the extremities where there is the highest tonus of the autonomic nerves. The sympathetic nerves which are distributed in the extremities are always able to relay the impulses of visceral sensation, because their outflow from the spinal cord begins in the thoracolumbar segments (T1-L2). This is a point of striking contrast with the spinal nerves there. (Fig 6 b) In spite of this fact, why did our investigations fail to produce referred pain at the end of the extremities? Perhaps it was because our methods of stimulation were inadequate for this purpose.

It is well known that patients who are suffering from gastric ulcer, bronchial asthma, angina pectoris etc. often complain that they feel chilly, pricking, or that they perspire freely on the palms of the hands and the soles of the feet. This is possibly due to the continuous influence of the visceral sensory impulses on the autonomic nerves of the extremities. These phenomena, however, are somewhat different from the radiation of the present abdominal pain. These syndromes are the result of long time stimulation of viscerogenic impulses and thus do not always need a strong stimulus as radiation cases which always cause pain.

II. Systematic Histological Study of Sensory Endings (SETO) in the Alimentry Canal.

by AKIRA OTSU, NOBUYOSHI TANAKA, HISASHI INOUE

Prof. H. SETO(Tohoku Universtiy)has observed with his staining method*, that sensory nerve endings are found in the esophagus, stomach, duodenum and anus in the alimentary canal. He believes that the sensory nerve endings of the esophagus and stomach belong to the n. vagus. To this thesis, we would like to add the following observations.

1. By physiological experiments we proved that there is sensation throughout the alimentary canal.
2. Prof. SETO maintains that the nerve endings (SETO) are sensible, because they are histologically quite different from "Terminalretikulum" (STOEHR jr.). But we felt that it was necessary to examine the sensory endings thoroughly and systematically,
3. As observed by many, we believe that the sensations of the esophagus and stomach are under the dual control of the vagus and sympathetic nerves.

1. Recently A. OTSU discovered that sensory nerve endings (SETO) also exist in the jejunum and rectosigmoid. Figs. (1) and (2) show the sensory nerve endings (SETO and the accompanying small nerve fibres that exist in the tunica mucosa of the jejunum. Figures (3) and (4) show sensory nerve endings in the mucous membrane of the jejunum which are unique because of their thickness and form. Figs. (5),(6),(7) and (8) show the sensory nerve (SETO) in the mucous membrane and in the submucous membrane of the jejunum.

In this specimen a gastrojejunostomy was performed to remove stomach ulcers. Six months later a resection was performed because ulcus pepticum jejuni was suspected. It is also of interest to observe the specimen in connection with the regeneration of the nerves at the point of anastomosis of the stomach and jejunum. At the point of anastomosis the mucous membrane of the stomach and the jejunum are interwoven and connective tissues are relatively few and have no clear-cut limits. The muscles of the stomach and jejunum, however, adhere together because of the development of connective tissues. At the point of anastomosis, the sensory nerve (SETO) enters the mucous membrane of the jejunum. See figs. (9), (10), (11) and (12). Sensory nerve fibres can be seen in the granulations and scar tissues at the point of suture of the muscles. See figs. (13),(14),(15), (16), (17), and (18). However, it is not possible to see the regeneration of the nerves between the muscles of the stomach and the muscles of the jejunum.

Because of the above it can be concluded that the sensory nerves (SETO) seen in figs. (1), (2), (3) and (4) exist in the jejunum.

In addition, nerve endings(SETO)have been discovered in the rectosigmoid of children's

* Seto's method ; a modified Bielschowsky's silver impregnation.

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megacolon specimen. Figs. (19), and 20) show the winding nerve endings (SETO) in the submucous membrane. Figs. (21), and (22) show the sensory nerves (SETO) in the tunica muscularis mucosae. Figs. (23), and (24) show the complex and tangled form of the nerve endings (SETO) in the circular muscle of the rectosigmoid. H. INOUE discovered the nerve ending (SETO) in the muscle under the mucous membrane of the gallbladder. See fig. (25).

According to the above, it can be assumed that sensory nerve endings (SETO) exist throughout the alimentary canal. Our physiological experiments are in agreement with this theory.

2. Prof. SETO asserts that endings of the autonomic nerves are 'Terminalretikulum" (STOEHR). See figs. (26),(27),(28). He believes that the nerve endings (SETO) are sensory endings because they are morphologically entirely different from the " Terminalretikulum," and they have the same shape as the sensory endings of the skin.

We questioned SETO's thesis. So we examined the following problems:

(A) Are the nerve endings (SETO) myelinated fibres?

(B) Do the nerve endings (SETO) degenerate when the roots of the nerves are cut?

(A.) A. OTSU and N. TANAKA found myelinated nerve fibres in the tunica submucosus, tunica muscularis mucosae and tunica propria of the esophagus and stomach. See figs. (29), (30), (31), (32), (33), and (34). Heretofore, the nerve endings (SETO) of the esophagus and stomach were found in the tunica muscularis and submucosa. We found them in the tunica muscularis mucosae and tunica propria. See figs. 35 , (36), (37), (38), (39), (40 , (41) and (42). According to the above it is certain that the nerve endings (Seto) are mostly myelinated nerve fibres. So we found the possibility of a solution to the problem.

(B A. OTSU found the degenerated myelinated nerve fibres in the tunica muscularis and in the tunica submucosa of the pylorus of a dog, both vagi of which were cut See figs. (44), (45), and (46). N. TANAKA cut one vagus of a dog. He used the Marchis staining method and found degenerated myelinated nerve fibres in the tunica muscularis, tunica submucosus and tunica muscularis mucosae of the esophagus. See figs. (47), (48), (49), (50) and (51).

These exepriments indicate that the nerve endings (SETO) can be degenerated by cutting the vagus. Therefore, it seems certain that a part of the nerve endings(SETO) belongs to the vagus. They do not change neurons in AUERBACH'S plexus and are still myelinated in the mucous membrane.

3. In the specimen of the stomach of a dog both vagi of which were cut we can find normal nerve endings (SETO) in the tunica muscularis mucosae and normal myelinated nerve fibres in the tunica submucosus. See figs. (52), and (53).

Therefore we assume that the nerve endings (SETO) do not belong to the vagus alone.

We tried to clarify the relationship between the nerve endings SETO and sympathetic nerves by cutting the posterior roots from Th8 to Th11 of the spinal cord of a dog. The specimen was then taken after 18 days. But we found only abnormal nerve formations in the muscle of the pylorus. See figs. (54), (55), (56), (57), (58), and (59).

The reason why the degeneration of nerves is incomplete even when the posterior roots are cut, is because the nerve cells are not in the spinal cord but in the spinal ganglions of the posterior roots So N. TANAKA resected the spinal ganglions from Th3 to Th7 of a dog. and took the specimen after 6 days. Using the Marchi's staining method he found degenerated nerve fibres in the tunica submucosa of the esophagus. See figs (60), (61), (62), and (63). These results are in agreement with the anatomical findings regarding the sensory nerve fibres, and are not inconsistent with the neuron theory.

CONCLUSION

1) The greater part of the nerve endings (SETO) are myelinated. By means of systematic observations, we conclude that they function as sensory nerves. 2) We also found nerve endings (SETO) in alimentary canals which have mesenterium. This fact is in accordance with our physiological findings 3) Sensation in the alimentary canal is innervated histologically by both sensory nerves of the vagus and the sympathicus

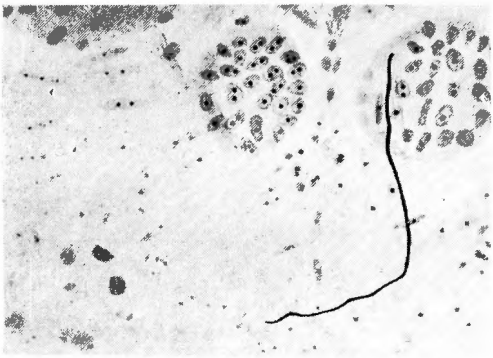

Fig. 1. Sensory erve ending (SETO) in the t. musc. mucos. of the jejunum.

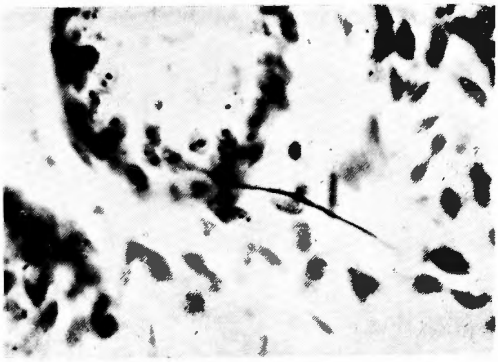

Fig. 2. Photomicrograph of a portion of fig. 1.

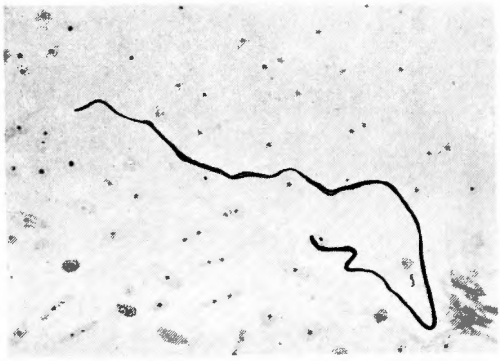

Fig. 3. Sensory nerve ending (SETO) in the musc. mucos. of the jejunum.

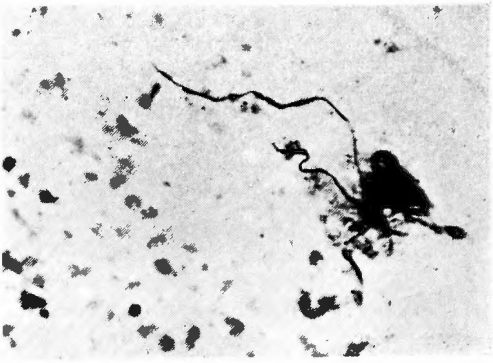

Fig. 4. Photomicrograph of the same ending as fig. 3.

Fig. 5. Sensory nerve fibre (SETO) in the musc. mucos. of the jejunum.

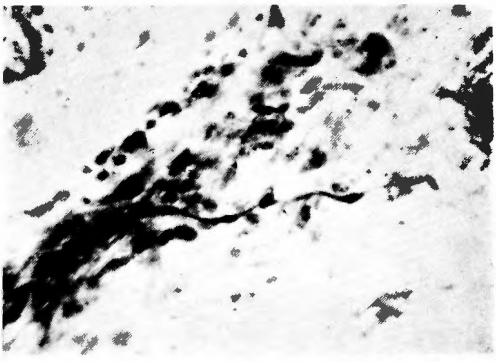

Fig. 6. Photo. of the same ending as fig. 5.

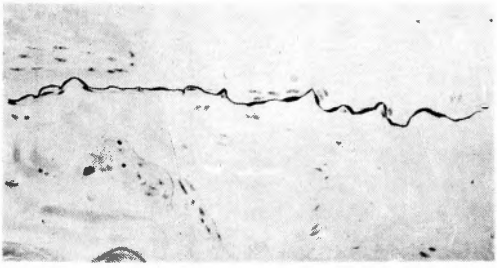

Fig. 7. Sensory nerve (SETO) in the t. submuc. of the jejunum.

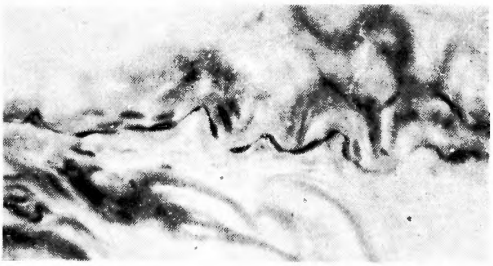

Fig. 8. Photo. of the same nerve as fig. 7.

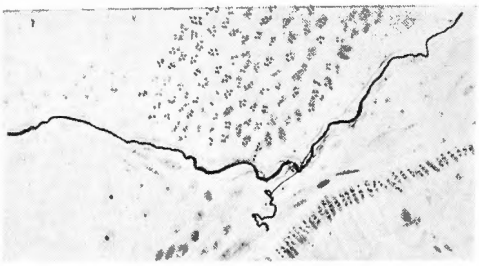

Fig. 9. Sensory nerve fibre (SETO) in the t. propria at the point of gastrojejunostomy. Jejunal side.

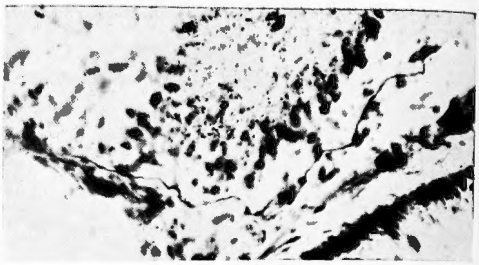

Fig. 10. Photo. of the same nerve as fig. 9.

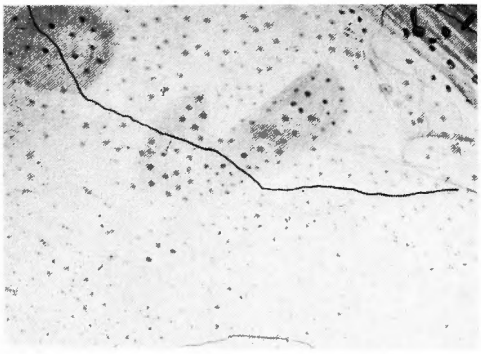

Fig. 11. Sensory nerve fibre (SETO) at the same place as fig. 9.

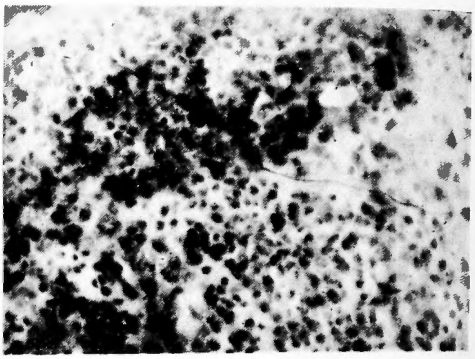

Fig. 12. Photo. of the same nerve as fig. 11.

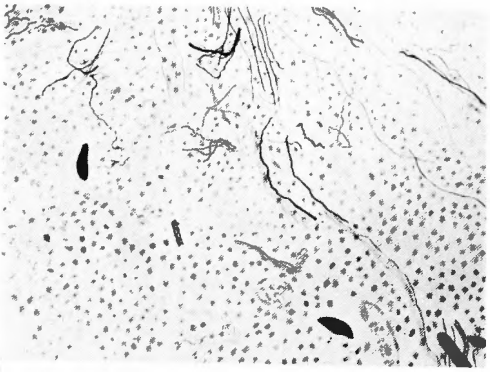

Fig. 13. Regeneration of nerve fibres in the granulation at the point of suture. Black spots are silk thread.

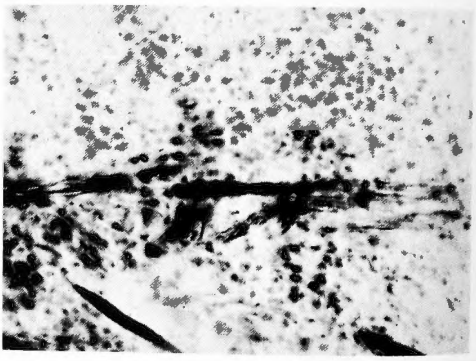

Fig. 14. Photo. of the the regenerated nerve fibres in the same area as fig. 13.

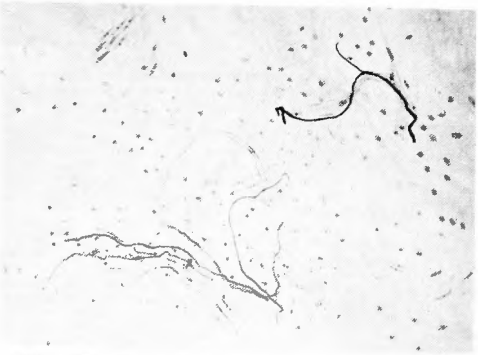

Fig. 15. Sensory nerve fibre (SETO) in the granulation with scar tissue.

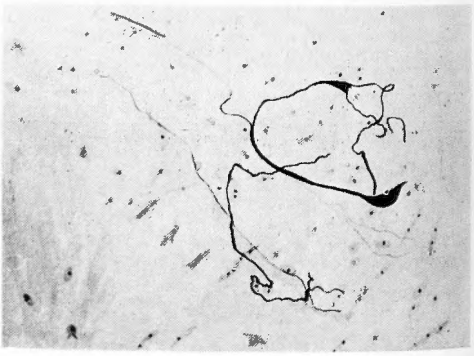

Fig. 16. Sensory nerve fibres (SETO) in the muscle, with Scar tissue.

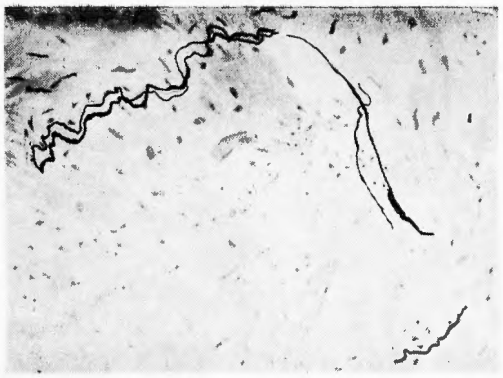

Fig. 17. Sensory nerve fibres in the scar tissue.

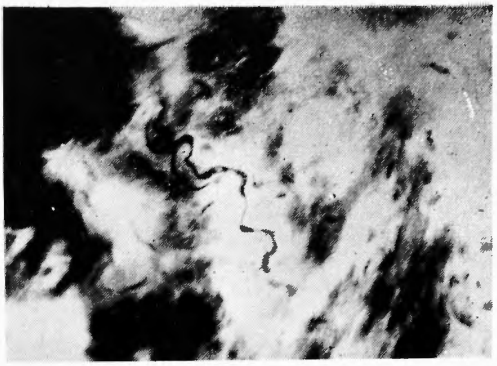

Fig. 18. Photo. of the same nerve as fig. 17.

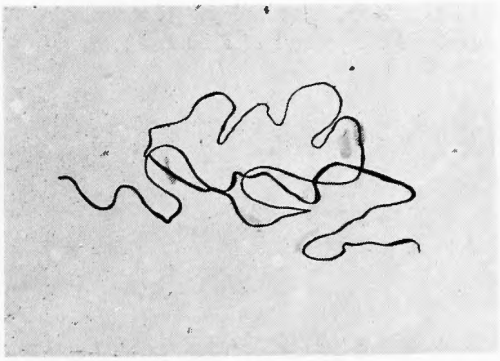

Fig. 19. Winding sensory nerve ending (Seto) in the t. submucos. of the rectosigmoid.

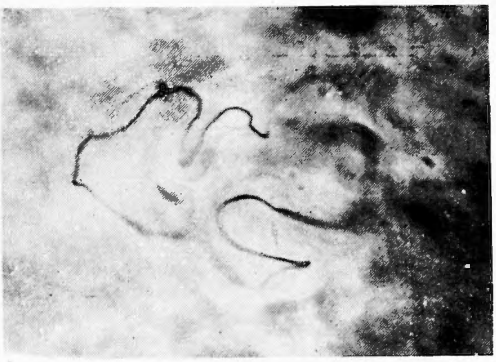

Fig. 20. Photo. of the same ending as fig. 19.

Fig. 21. Sensory nerve fibres (Seto) in the t. musc. mucos. of the rectosigmoid.

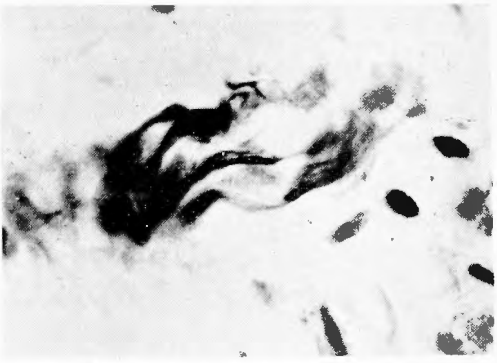

Fig. 22. Photo. of the same nerve as fig. 21.

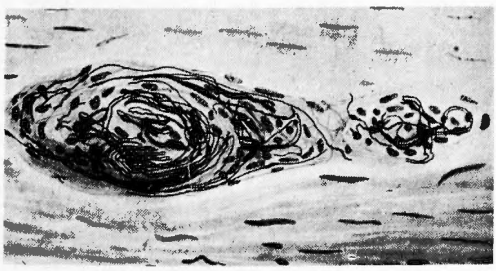

Fig. 23. Complex and tangled sensory nerve ending (Seto) in the circular muscle of the rectosimoid.

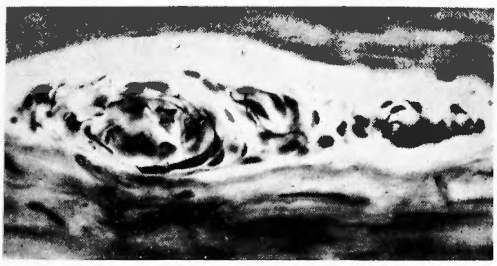

Fig. 24. Photo. of the same ending as fig. 23.

Fig. 25. Sensory nerve ending (SETO) under the mucous membrane of the gallbladder of a human being.

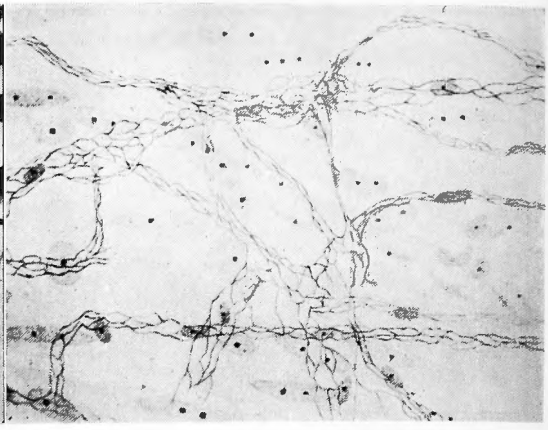

Fig. 26. "Terminalretikulum" (STOEHR) in the muscle of the pylorus of a human being.

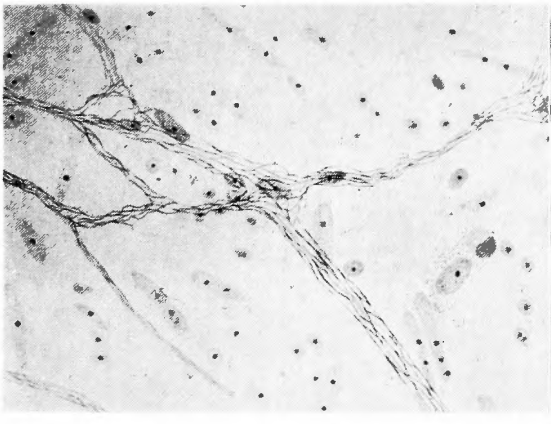

Fig. 27. "Terminalretikulum" in the t. musc. mucos. of the pylorus of a human being.

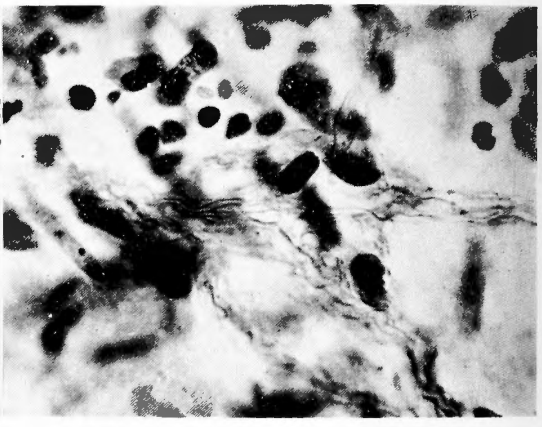

Fig. 28. Photo. of the "Trminalretikulum" in the same slide as fig. 27.

Fig. 29. Myelinated nerve fibres in the t. submucos. of the pylorus of a human being.

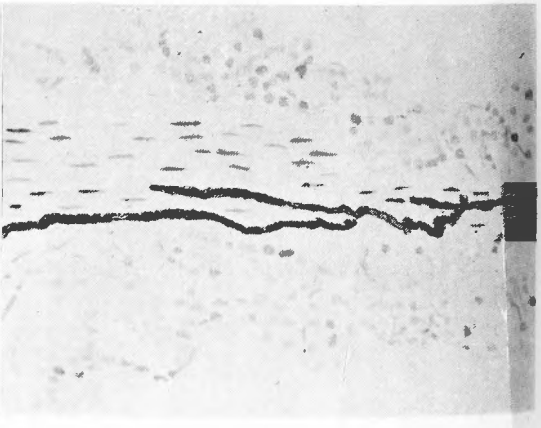

Fig. 30. Myelinated nerve fibres in the t. musc. mucos. —t. propria of the pylorus of a human being.

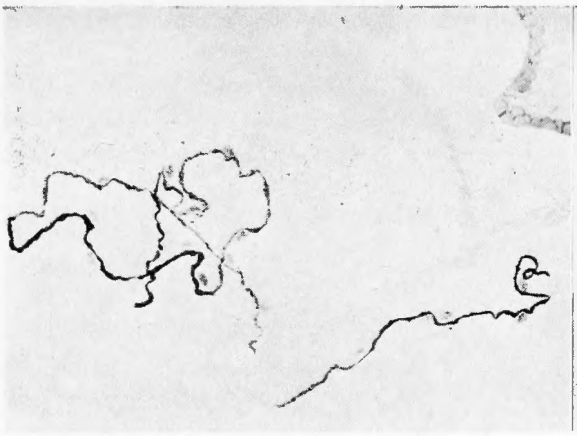

Fig. 31. Myelinated nerve fibres in the t. submucos. of the pylorus of a dog.

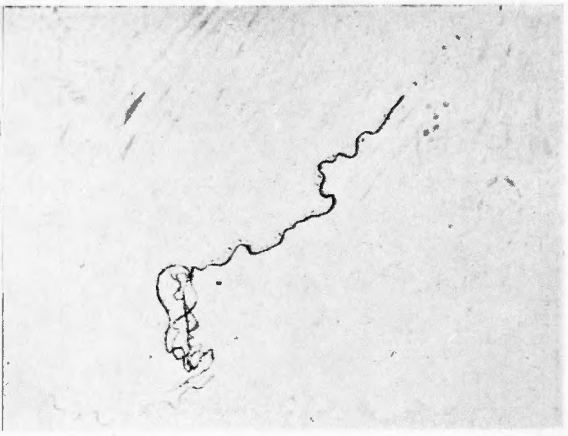

Fig. 32. Myelinated nerve fibre in the t. submucos. —t. musc. mucos. of the pylorus of a dog.

Fig. 33. Myelinated nerve fibres in the t. submucos. of the esophagus of a dog.

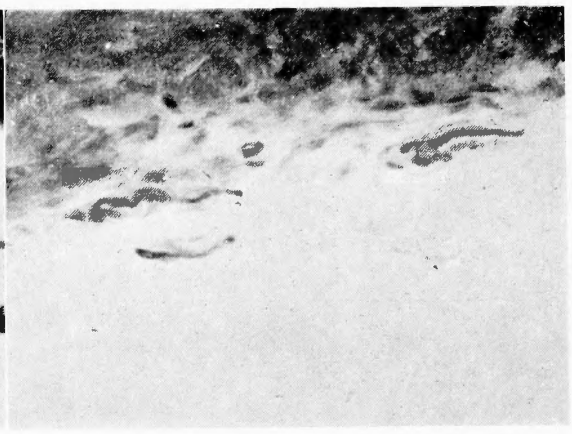

Fig. 34. Enlargement of the same nerve as fig. 33.

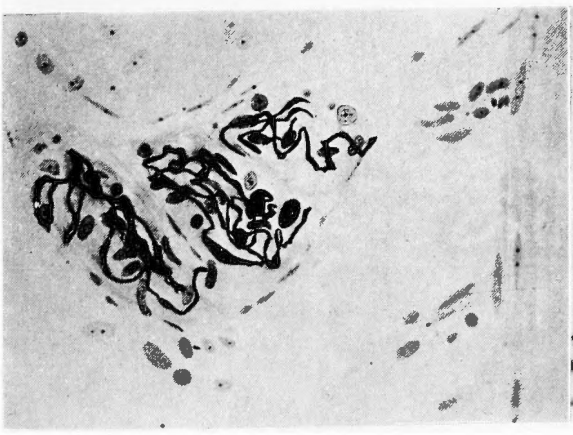

Fig. 35. Sensory nerve ending (SETO) in the t. submucos. – t. musc. mucos. of the pylorus of a human being.

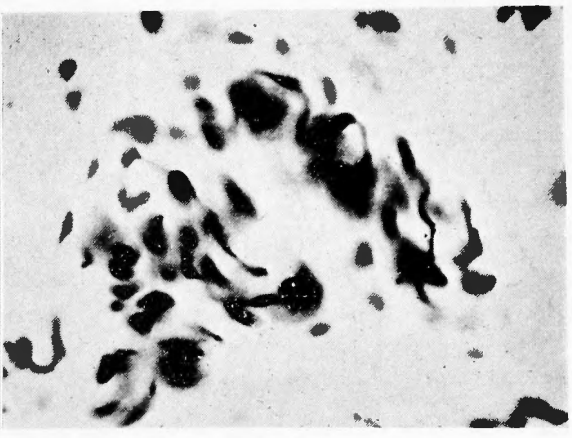

Fig. 36. Photo. of the same nerve ending as fig. 35.

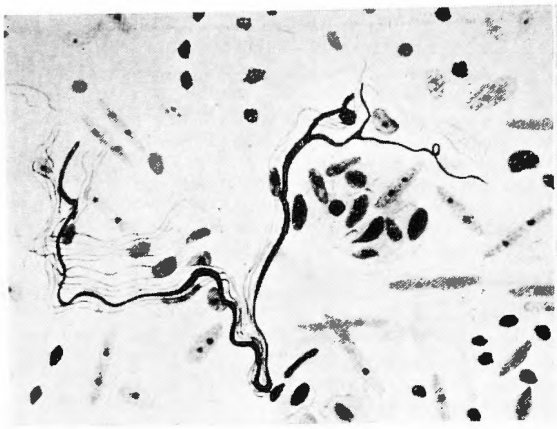

Fig. 37. Sensory nerve ending (Seto) in the t. musc. mucos. of the pylorus of a human being.

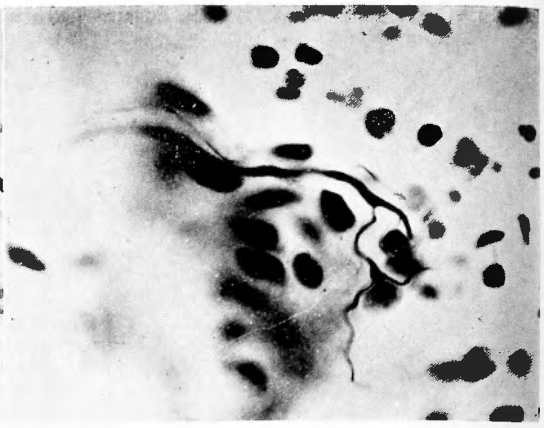

Fig. 38. Photo. of the same ending as fig. 37.

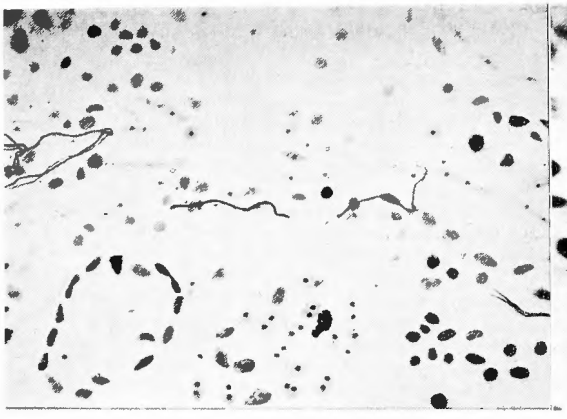

Fig. 39. Sensory nerve ending (Seto) in the t. prop. of the pylorus of a human being.

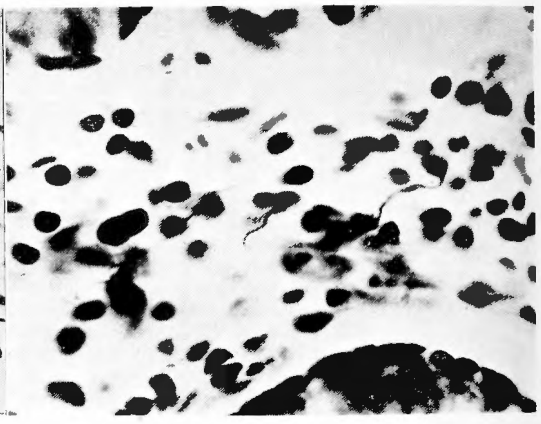

Fig. 40. Photo of the same ending as fig. 39.

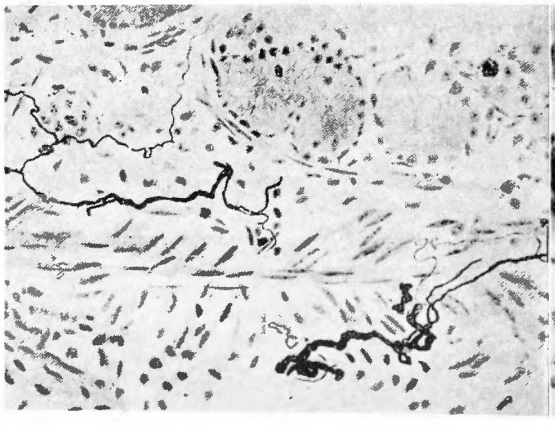

Fig. 41. Sensory nerve ending (Seto) in the t. musc. mocos. —t. prop. of the pylorus of a dog.

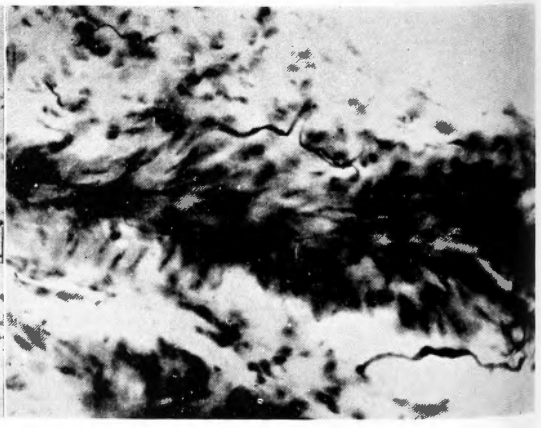

Fig. 42. Photo. of the same ending as fig. 41.

Fig. 43. Degenerated myelinated nerve fibres in the muscle of the pylorus of a dog, both vagal nerves of which were cut.

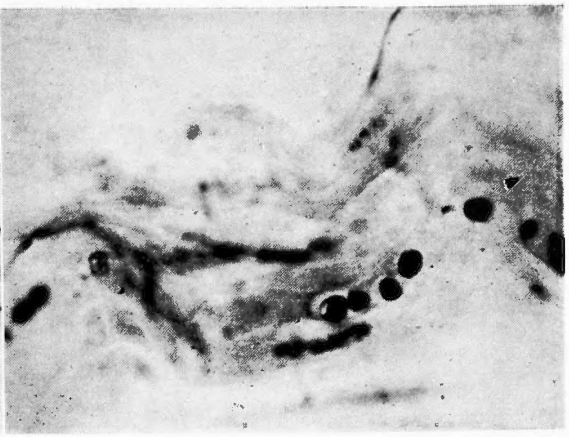

Fig. 44. Enlargement of a portion of fig. 43.

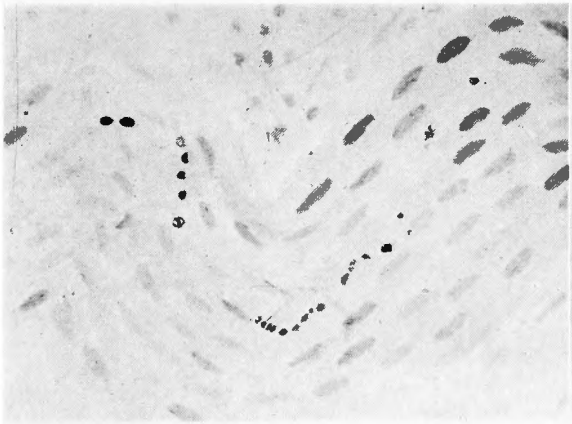

Fig. 45. Adegenerated myelinated nerve fibre in the t. submuc. of the pylorus of a dog, both vagal nerves of which were cut.

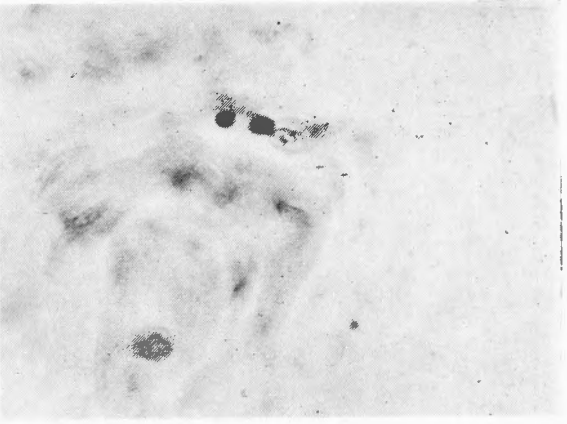

Fig. 46. Enlargement of a portion of the same nerve as fig. 45.

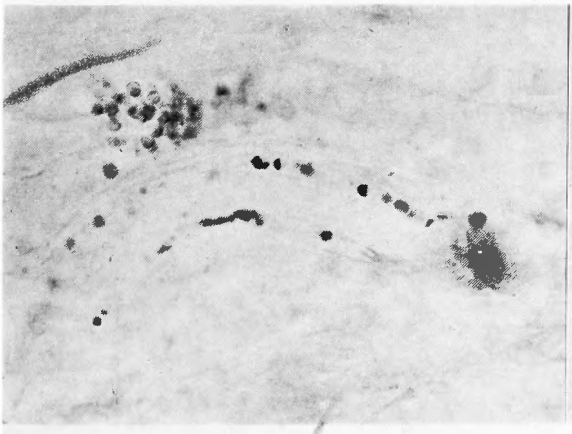

Fig. 47. Degenerated myelinated nerve fibres in an AUERBACH'S plexus of the esophagus of a dog, one vagal nerve of which was cut. (MARCHI'S method.)

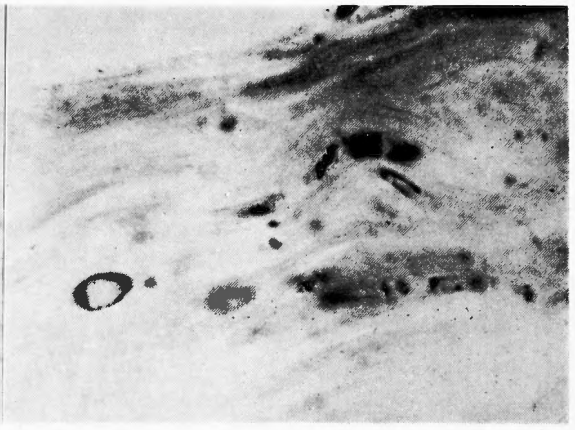

Fig. 48. Degenerated myelinated nerve fibres in an Auerbach's plexus of the esophagus of a dog. both vagal nerves of which were cut. (SETO'S method,)

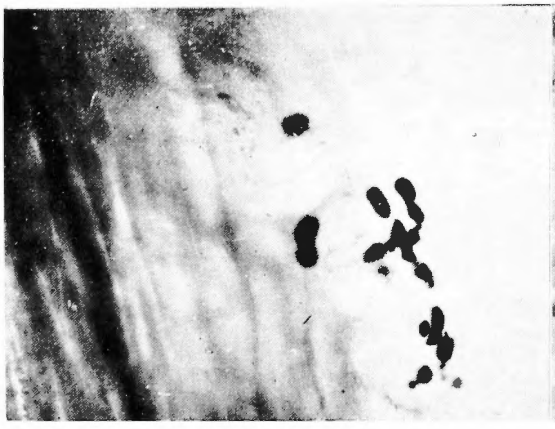

Fig. 49. Degenerated nerve fibres in the muscle of the esophagus of a dog, one vagal nerve of which was cut. (MARCHI'S method.)

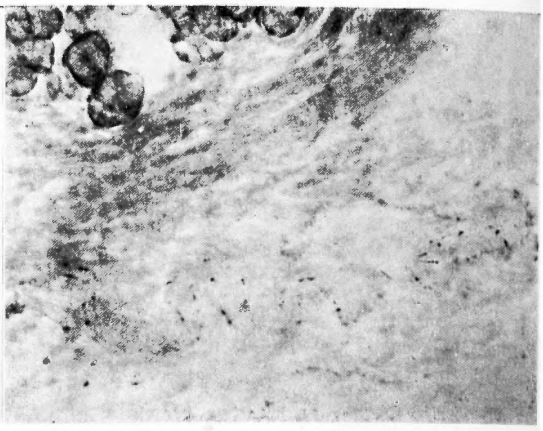

Fig. 50. Degenerated myelinated nerve fibres in the t. submuc. of the esophagus of a dog, one vagal nerve of which was cut. (MARCHI'S method.)

Fig. 51. Degenerated nerve fibres in the muscle of the esophagus of a dog, one vagal nerve of which was cut. (SETO's method.)

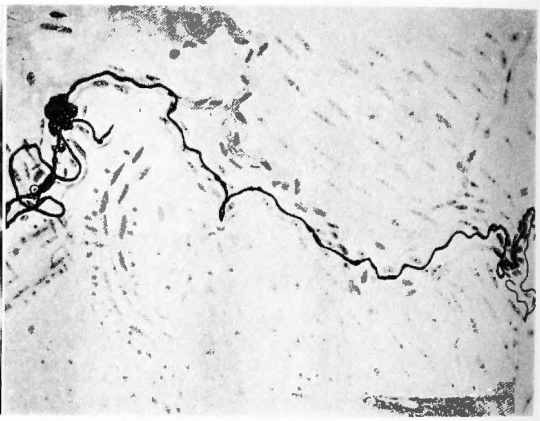

Fig. 52. Sensory nerve ending (SETO) in the t. musc. mucos. of the pylorus of a dog, both vagal nerves of which were cut.

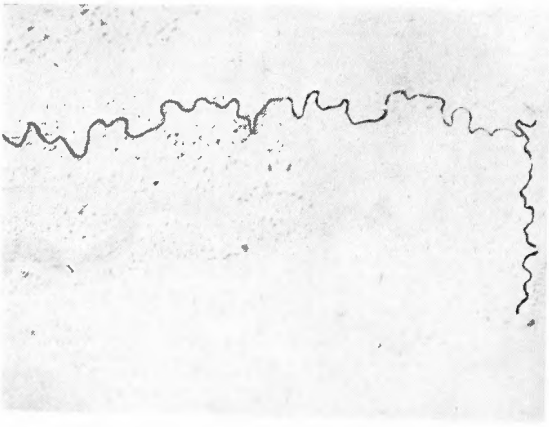

Fig. 53. Normal myelinated nerve fibres in the t. submucos. of the pylorus of the same specimen as fig. 52.

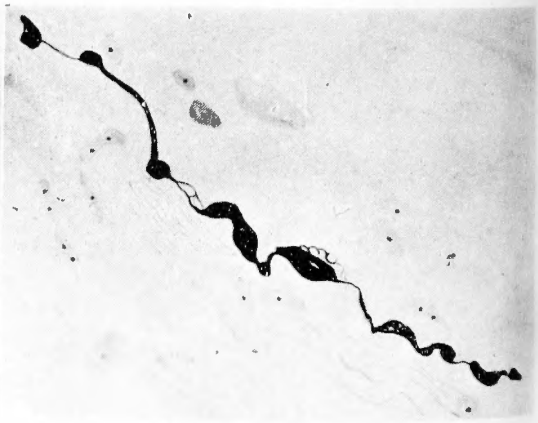

Fig. 54. Abnormal nerve fibres in the muscle of the pylorus of a dog, the posterior roots from 8Th to 11Th of which were cut.

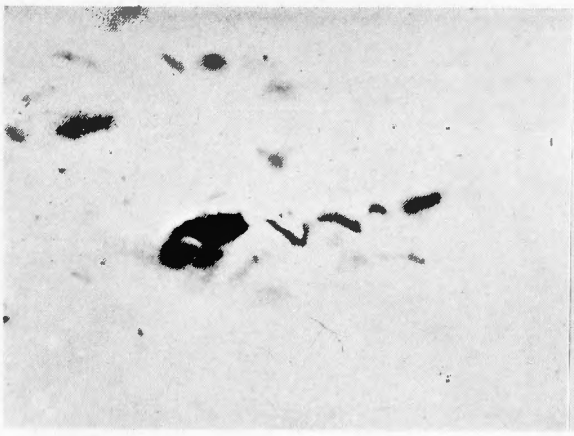

Fig. 55. Photo. of the same nerve as fig. 54.

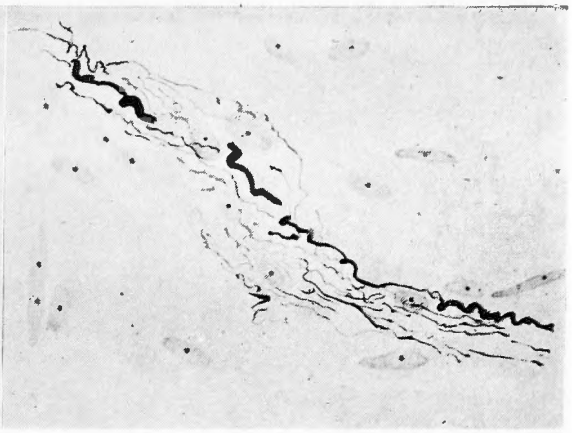

Fig. 56. Abnormal nerve fibres in the same specimen as fig. 54.

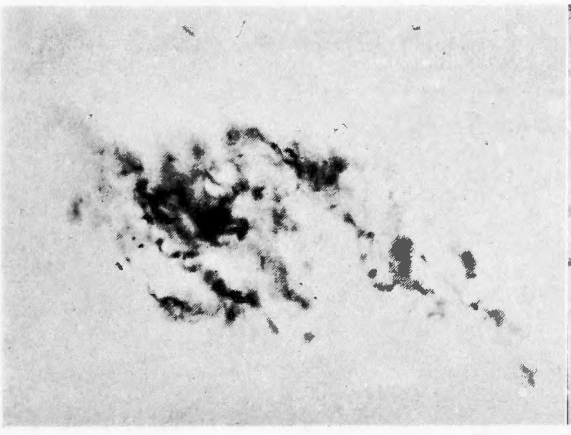

Fig. 57. Abnormal nerve fibres in the same specimen as fig. 54. Photo.

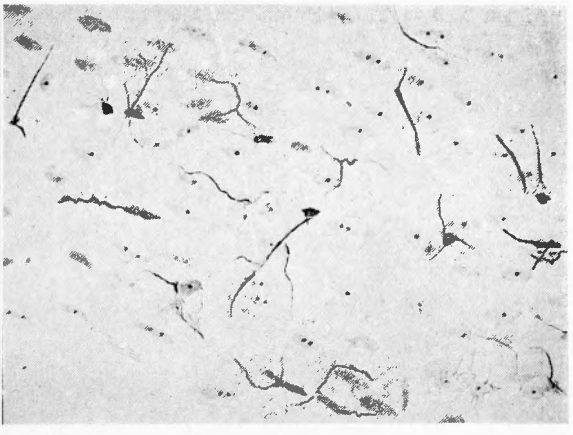

Fig. 58. Abnormal nerve fibres in the muscle of the same specimen as fig. 54.

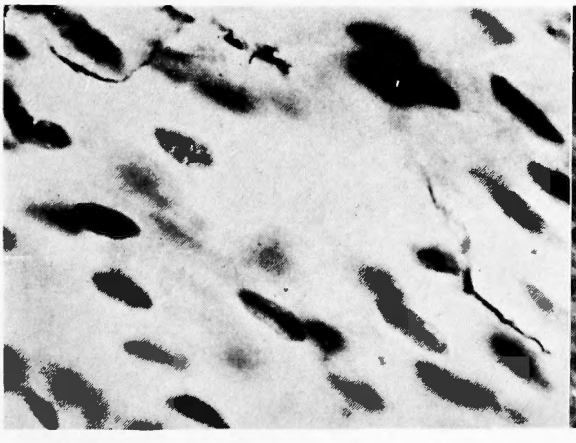

Fig. 59. Photo. of the same nerve as fig. 58.

Fig. 60. Degenerated nerve fibres in the muscle of the esophagus of a dog, the spinal ganglions from 3Th to 7Th of which were resected. (MARCHI's method)

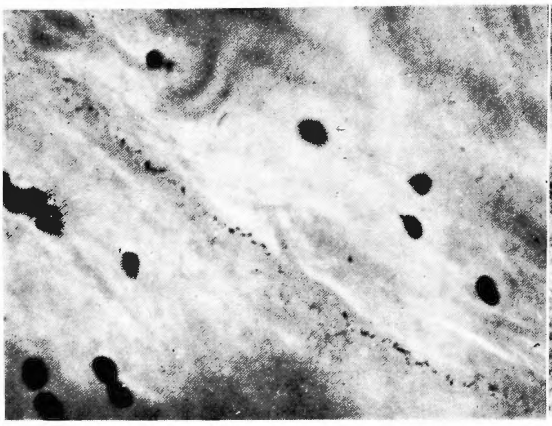

Fig. 61. Degenerated nerve fibres in the t. musc. —t. submucos. of the same esophagus as fig. 60. 6 days after the posterior spinal ganglionectomy from Th3 to Th7. (Marchi's method.)

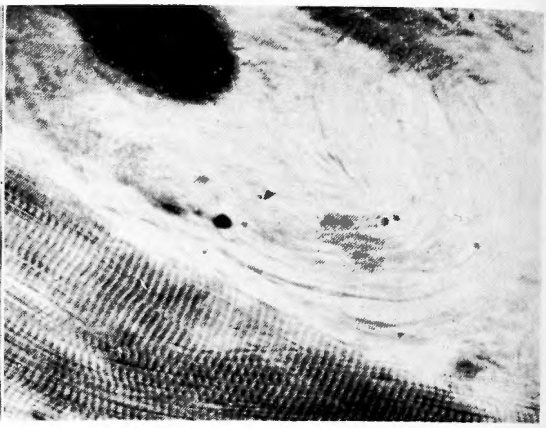

Fig. 62. Degenerated nerve fibres in an AUERBACH'S plexus of the same esophagus as fig. 60. (Marchi's method.)

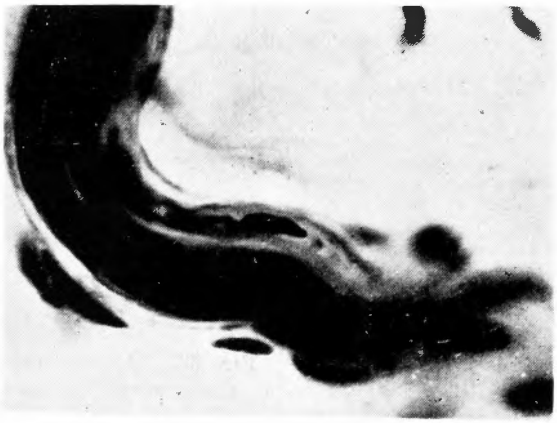

Fig. 63. Degenerated nerve fibres in the t. submucos. of the same esophagus as fig. 60. (SETO'S method.)