A HISTOLOGICAL STUDY OF SENSORY NERVES IN THE ASCENDING, TRANSVERSE, AND DESCENDING COLON

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I. INTRODUCTION

Many clinicians have stated that the morbid colon becomes painful following its accelerated peristalsis due to stimulation. CH. KIMURA (Assist. Prof. of our clinic) confirmed that the whole alimentary canal has sensitivity on the basis of physiological experiments using KIMURA's acetylcholine method and by mechanical stimulation. He clarified that pain of colon is felt on the medial line reaching from the subumbilical region to the suprapelvic region. He also determined, on the basis of his physiological experiments, which of the vagal, thoracolumbal and sacral nerves had dominant innervation in each organ.

The results of KIMURA's physiological experiments also showed that the mucous membrane of the whole alimentary tract is provided with sensory nerve endings. But, from the anatomical point of view, the sensory nerves of the ascending, transverse, and descending colon have not been clearly prove. H. SETO (Prof. of anatomy : Tohoku University) advocated the theory of the autonomic "terminalreticulum" (STÖHR and REISER, 1932). Besides the autonomic nerve ending in a network, he observed in the viscera a special kind of nerve having free endings and distinctly thicker diameters than autonomic nerve fibers. He described that they had the same appearance of somatic sensory nerves. He introduced his theory that these thick nerves having free endings were sensory nerves in the viscera. He established that these sensory nerves are distributed to the esophagus, stomach, duodenum, anus, ovary and pancreas by demonstrating their free endings in these organs.

Afterwards OTSU of our clinic (1953) found the endings of sensory nerves in the mucous membrane of the jejunum and sigmoid colon, MAKINO (1955) in the ileum and cecum, and WANG (1955) in the sigmoid and rectum. They proved the sensory nature of these nerves by means of secondary degeneration following the experimentary posterior rhizotomy together with spinal ganglion or by section of vagal nerve trunks. They recommended the obsevation of these secondary degenerations are carried out in the more peripheral layers than in AUERBACH's or MEISSNER's plexus where autonomic nerves already changed their neurons. By this method they could differentiate these degenerated sensory nerves from those of preganglionic autonomic nerves, because they do not reach the mucous membrane beyond these nerve plexus and the postganglionic fibers in mucous membrane do not degenerate

following vagotomy or posterior rhizotomy including the spinal ganglia.

The author studied those sensory nerves and their endings of the alimentary tract in the ascending, transverse, and descending colon, where they were still unknown. The author then studied the degeneration experiments of these nerves to confirm the sensory nature and the source of them.

Cutting various parts of spinal roots including spinal ganglions or the vagus nerve, the author's study was pursued to determine which of these parts had the predominant sensory innervation in the ascending, transverse, and descending colon.

II. MATERIALS AND METHODS

The author used only fresh specimens, taken from human ascending, transverse, and descending colon without inflammatory changes or neoplasms which were resected operatively. They were fixed in 10% neutral formol solution for 3～4 weeks, and then cut in 30～40μ thick sections by the freezing method. Preparations were kept in 10% neutral formol solution again for at least 2 months before staining.

Dogs were used as experimental animals and the degenerated nerve fibers in their colons were examined after operation. Operations were carried out on the dorsal roots of the spinal cord distal to spinal ganglions, their ventral roots, and on the vagus nerve. All the dogs were operated on under general anesthesia with the injection of isomytal-sodium. Thoracotomy was performed for vagotomy, and vagotomy on both sides was performed concurrently in the thorax.

The axis cylinder of the nerve was stained with SETO's modification (SETO's Method) or SUZUKI's modification of BIELSCHOWSKY's silver impregnation (SUZUKI's Method).

Before removing the specimen, the part of colon was injected with 5,000 VRU of HYARONIDASE solved in lcc of physiological saline solution. After the injection of the HYARONIDASE solution the specimen was removed and fixed in 10% neutral formol solution for 1～2 days until they are cut into sections by the freezing method. The sections were further fixed for one day. Then the nerves were stained by SETO's or SUZUKI's method. This was done following WEDDELL's method. This HYARONIDASE method seemed to be practicable, because staining was completed within 3 days to 1 week after the removal of the specimens.

For examining myelinated nerves only or clarifying their degeneration, EHRLICH's acid hematoxline method was used.

SETO's Method

The specimens, which were cut according to the freezing method and kept in neutral formol solution, are :

1) washed with distilled water for a few minutes,
2) put into 20% silver nitrate solution, for 24～48 hours, in the darkness,
3) washed in distilled water for 20～30 seconds,
4) put into 20% neutral formol solution this

SUZUKI's Method (Modified by author as follows)

The specimens, which were cut according to the freezing method and kept in neutral formol solution, are :

1) washed 3 times with distilled water, each time for 10 minutes,
2) immersed in 20% silver nitrate solution, for 1 hour, in the darkness,
3) washed with distilled water for several

solution must be made by diluting the mother neutral formol only with running water, and placed in 4~5 plates. The specimens were transferred to these plates one by one until the white precipitation disappeared,
5) washed with running water for 30~50 seconds,
6) placed on filter paper to blot up the water,
7) immersed in 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 with distilled water for 3 minutes,
11) placed in 20% sodium thiosulfate solution until the specimens were colored reddish brown,
12) washed in distilled water,
13) dehydrated and mounted.

seconds,
4) immersed in ammoniacal silver solution until the specimens were colored light yellow (for about 5 minutes),
5) placed in 10% sodium-potassium tartrate solution for 20 seconds, and once more placed in fresh 10% sodium-potassium tartrate solution until the specimens were colored golden yellow,
6) washed with distilled water for 5 minutes,
7) placed in 0.05~0.1% gold chloride solution for 1~2 hours,
8) washed with distilled water for 5 minutes,
9) placed in 20% sodium thiosulfate solution,
10) washed in distilled water,
11) dehydrated and mounted.

III. SENSORY NERVE ENDINGS IN THE ASCENDING, TRANSVERSE, AND DESCENDING COLON.

In all layers of the ascending, transverse, and descending colon of human beings and dogs, there was observed the "terminalreticulum" of the autonomic nerve, so called by STÖHR JR. and REISER; it did not end in free endings, even in the mucous membrane, but its neurofibrils made a network which surrounded the crypts of the intestine. (Fig. 1, 2.)

In the nerve bundles which entered the muscular layer from the subserous layer, there were thick fibers with varicosities which were clearly distinguished from multitudious fine autonomic nerve fibers. These thick fibers, bearing no synaptic relationship with the nerve cells in the myenteric plexus (Fig. 3.), ran through the inner circular muscle reaching the submucous layer (Fig. 4.); waving on the way, they ran alone (Fig. 5. SN.) or with autonomic nerve fibers in the submucous layer and terminated either in free tapering endings or simple ramified endings in the submucous layer, lamina muscularis mucosae, laimina propria mucosae or in the surrounding interstitium of the intestinal crypts. The endings of these thick fibers were pointed, not club-shaped or nodular. (Fig. 6, 7, 8, 9.)

Most of these endings were observed in the lamina propria mucosae and lamina muscularis mucosae. Some were found in the submucous layer. Very few of them were found in the muscular layer. Thus, the free ending thick nerve fibers with varicosities which were observed in the ascending, transverse, and descending colon can be identified morphologically with the sensory nerves which were found by SETO.

On staining the myelin sheath, a considerable number of myelinated nerves were found, although not in a uniform distribution, in all the layers of the ascending, transverse, and descending colon. These myelinated nerves, contained in the non-myelinated nerve bundle, enter the muscular layer through the myenteric plexus eventually reaching the submucous layer; a few of them were found in the lamina muscularis mucosae, and lamina propria mucosae, as well as between the crypts of

the intestine. (Fig. 10, 11, 12.) These myelinated nerves were correspondent in shape and distribution with those which were identified with the sensory nerves which were found by SETO stained with the silver impregnation.

Preganglionic autonomic nerves may be myelinated, but they relay neurons in the intramural plexuses and become non-myelinated. Even though postganglionic autonomic nerves are myelinated, autonomic nerves change into a reticular structure in the periphery.

In the mucous membranes these autonomic nerves represent terminal networks which consist of only neurofibrils. It is confirmed that those myelinated fibers which pass through the intramural plexuses and are present in the periphery are sensory nerves. The above mentioned findings have led to the following conclusions that: 1) the sensory nerves in the colon are myelinated; 2) they do not relay neurons on their way to the peripheral layer; 3) they keep their myelin sheaths close to their terminals in the periphery.

(1) Sensory nerve endings in the ascending colon.

In the muscular layer of the ascending colon, thick and wavy sensory nerve fibers with varicosities were found with the thin autonomic nerve fibers, and they ran through AUERBACH'S plexus.

These nerves found their way to the submucous layer. Some of them ended in tapering terminals in the layer. Most of them entered the lamina muscularis mucosae independently or accompanied by autonomic nerves and then ended in serpentine free terminals. (Fig. 13.)

In the ascending colon, of the human being, some nerves were found going to the lamina propria mucosae. They were tapering in a marked winding course ending in free terminals. (Fig. 14.) But very rarely such terminals ended at the base of the crypts of the intestine. The endings of sensory nerves which were found in the ascending colons of human beings and dogs were rather small in number. Their shapes were mostly simple and unbifurcated. Generally the innervation of sensory nerves in the ascending colon was poor.

On myelin sheath staining, myelinated nerves were observed to rarely enter the lamina muscularis mucosae from the submucous layers. (Fig. 15.) In the submucous layers and the mucous membranes of the ascending colon, myelinated nerves were less in number than those in the transverse and descending colon. This finding corresponded with the result of the silver staining of sensory nerve endings.

In one case of CROHN'S disease, abnormally deformed sensory nerve fibers were found in the inflamed area in the ascending colon. These sensory nerve fibers showed clubbed or ampullar swellings in some parts of AUERBACH'S plexus. In the same specimen, similar ampullar swellings looked like beads in the submucous layer and lamina muscularis mucosae. (Fig. 16.)

(2) Sensory nerve endings in the transverse colon.

In the transverse colon, also thick and wavy sensory nerve fibers with varicosities entered AUERBACH'S plexus running alone or accompanied by non-myelinated fibers. (Fig. 3.) A simple bifurcated sensory nerve ending was also found in the

circular muscular layer. Most of the sensory nerve fibers passsing through the muscular layer and the submucous layer, entered the lamina muscularis mucosae. (Fig. 4, 5, 6.) Part of them distributed in unforked endings or simple bifurcated endings in the submucosa without any relation to the ganlion cells in MEISSNER'S plexus. Some of them ran along the blood vessels of the submucosa, or tangled these blood vessels and ended at the wall. (Fig. 17, 18.) Most of the sensory nerves terminated in the lamina muscularis mucosae (Fig. 5, 6, 19, 20.), in the lamina propria mucosae or between the crypts of the intestine in unforked or simple ramified endings. (Fig. 7, 21.) Generally, more sensory nerve endings were observed in the transverse colon than in the ascending colon. They showed more complicated and more specific forms in the transverse colon.

Corresponding with the course of these nerves, medium calibered myelinated fibers were demonstrated in mucous membrane by EHRLICH'S myelin sheath staining. (Fig. 22, 23.) They were found to be more numerous in the transverse colon than in the ascending colon. In the submucous layer of the transverse colon of a dog, there was a nerve which was bifurcated keeping the myelin sheath.

(3) Sensory nerve endings in the descending colon.

Sensory nerve endings in the muscular layer of the descending colon were very few. (Fig. 24) In the submucous layer, there were found unforked, simple forked, or arborized endings of sensory nerves. (Fig. 25, 26.) Fig. 25 shows free sensory nerve endings which bifurcate on the blood vessel's wall in the submucous layer. Sensory nerve endings were also observed in the lamina muscularis mucosae. Most of them running by themselves or accompanied by autonomic nerves distributed in the lamina propria mucosae with unforked or simple arborizing endings. (Fig. 27, 28.) A considerable number of them ended very close to the epithelial cells of the crypts. (Fig. 8, 30.) Some sensory endings ran perpendicularly upwards between the crypts. (Fig. 29.) None of them entered into the crypts of the intestine. Sensory nerve endings in the descending colon were found to be more numerous than in the ascending or transverse colon. In the descending coln, the more distal, the more sensory nerve endings were found. The form of these endings looked more ramified, and the number of them in the surrounding area of intestinal crypts were greatly increased in the descending colon compared to the ascending or transverse colon. But neither tangled nor specific organized endings were demonstrated.

On myelin sheath staining, medium calibered myelinated nerves in the submucous layer of the descending colon were found far more than in the ascending and transverse colon; most of them were 3.3～4.0μ in diameter. A small number of the maximum calibered fibers (over 7μ in diameter) was observed in the muscular layer and submucous layer, but not in the ascending or transverse colon.(Fig. 31.) In other parts of the colon, myelinated nerves in the mucous membrane were rare, but they increased considerably in the descending colon.(Fig. 32.) In the submucous layer of the descending colon, there was found bifurcation of myelinated nerves keeping their myelin sheaths.(Fig. 33.)

IV. SYSTEMATIC OBSERVATION OF THE SENSORY INNERVATION IN THE ASCENDING, TRANSVERSE, AND DESCENDING COLON

(1) Degeneration experiments of sensory nerves.

LANGLEY, FÖRSTER, RANSON, CLARK, BALCHUM, WEAVER, CANNON, ISHIKAWA, KUBO, ASAI, HIRAMATSU and others physiologically demonstrated that visceral afferent nerves pass through posterior roots and the sympathetic trunk. These findings were histologically supported by SHEEHAN, KUNTZ and other investigators in our clinic. According to these authors, these afferent visceral nerves start from the nerve cells in the spinal ganglions and reach the effective organs without changing their neurons on the way.

On the other hand, RANSON, FOLEY, ALPERT and others insist from the physiological standpoint that the visceral afferent nerves are derived from the vagus.

TANAKA, OTSU, MAKINO and WANG in our clinic found the degenerated nerves more in the peripheral layers than in the intramural plexus in the digestive tract following the experimentary posterior rhizotomy together with spinal ganglion or cutting vagal nerve trunks. From these findings they concluded that the special nerves, which were found by Prof. SETO and called, by KIMURA and OTSU, sensory nerves, resulted from posterior roots of the spinal cord or vagus nerve and without changing their neurons in AUERBACH's plexus or in MEISSNER's plexus went to the mucous membrane. Therefore, they recommended the differentiation method of these sensory nerves from autonomic nerves by tracing these secondary nerve degenerations to the more peripheral layers than to AUERBACH's and MEISSNER's plexus, where autonomic nerve degeneration can be found no more. By this tracing they distinguished the degenerated sensory nerves from the preganglionic nerve fibers of autonomic nerves.

Using these methods, the author also tried to demonstrate these characteristics of visceral sensory nerves in sensory nerves in the colon by means of degeneration experiments of the myelin sheath or axis cylinder.

(a) Section of the dorsal roots of the spinal cord.

The dorsal roots were carefully separated from the ventral roots, and only the dorsal roots were bilaterally resected at a point distal to their ganglia; 4.5～5 days later, the degenerated picture of the myelinated nerve fibers in various parts of colon was studied. On the basis of the divisions of where the posterior rhizotomy was done, the experimental animals were classified into following 6 groups:

Group 1……TH. 9～TH. 12
Group 2……TH. 13～L. 4
Group 3……S. 1～S. 3

In these 3 groups there were found many degenerated myelinated nerve fibers in the ascending, transverse, and descending colon. The degenerated myelinated nerve fibers were markedly deformed, showing a swelling and splitting like oil drops or granules. (Fig. 34～40.) They were clearly distinguished from normal fibers. Such degeneration was found not only in the nerves which pass through the muscular layer, and myenteric plexus, but also in the myelinated nerves entering the

submucous layer, lamina muscularis mucosae, and lamina propria mucosae. (Fig. 34~40.) Especially in the myelinated nerves which run between the intestinal crypts a clear finding or degeneration was demonstrated. (Fig. 38.) On the silver impregnation, the axis cylinder was destroyed and swollen containing occasional vacuoles or granular splits. These findings are nothing but degeneration of the axis cylinder. (Fig. 34, 35, 43, 44.) Such rhizotomy, however, caused degeneration neither in the terminal network of the autonomic nerve, nor in winding territory (Schlingenterritorium by STÖHR).

Group 4·····TH.5~TH.8

In this group, no degeneration of nerve fibers was found in any region of the colon.

Group 5·····L.5~L.7

Only in Auerbach's plexus of the descending colon were a few degenerated nerve fibers observed. However, they did not suggested degeneration of sensory nerves.

Group 6 ····· S.3~Coc.1

No degenerated nerve fibers were found in the ascending, transverse, or descending colon.

(b) Section of the ventral roots of the spinal cord

The bilateral ventral roots were carefully separated from the dorsal roots and were resected distally to the ganglia; 4.5~5 days later, degeneration of myelinated nerve fibers in the ascending, transverse, and descending colon was studied.

Section of the ventral roots of TH.12~L 2

Section of the ventral roots of S.1~S.3

In these groups, no degenerated nerve fibers were detected in any part of the colon.

(c) Section of the vagus nerve.

On thoracotomy, both thrunks of the vagus 2~3cm above the diaphragm were simultaneously disected and cut. Seven days after the vagotomy, very few degenerated myelinated nerve fibers were found in AUERBACH'S plexus and in the submucous layer of the ascending colon only. They showed a swelling, splitting and granules which were clearly different from normal myelinated nerve fibers. (Fig. 41, 42.) These degenerated fibers were the medium calibered myelinated nerves and they reached the submucous membranes. Supposing these were efferent vagal fibers, they would change neurons at the myenteric plexus and become non-myelinated thereafter. Moreover, these nerves correspond to medium calibered myelinated fibers, which were demonstrated as sensory nerves by HEINBECKER, TAZAKI and OSAKI. Thus, these degenerated myelinated nerves following vagotomy were considered sensory in nature passing through the vagus. On vagotomy, no changes were found in the terminal network of autonomic nerve or in winding territory (Schlingenterritorium by STÖHR).

(2) Distribution of the degenerated sensory nerves in the ascending, transverse, and descending colon following vagotomy and posterior rhizotomy.

Bilateral vagotomy was performed in the thoracic cavity; posterior rhizotomies were done in the following groups; (TH.6～TH.8), (TH.9～TH.11), (TH12～L.1), (L.2～L.4) and (S.1～S.3). The number of degenerated sensory nerves in the ascending, transverse, and descending colon was counted, and then the distribution was surveyed. In the present experiment, 7 days after vagotomy, and 4.5 days after rhizotomy, 1.5×1.5cm blocks were taken from the middle parts of the ascending, transverse, and descending colon and 40μ thick sections were made. From each colon, 40 sections were observed. In each section layers from muscular layer to mucous membrane appeared. The percentage of the degenerated sensory nerves in each part of the colon was computed. In each group, 3 adult dogs were used. The average value of the data is shown in Table 1. In the ascending

Table 1. (T. 1.)

Distribution of the degenerated sensory nerves in each part of the colon of the dog after posterior rhizotomy and vagotomy

	Ascending colon	Transverse colon	Descending colon	Sigmoid colon
bilateral Vagotomy	3 %	0 %	0 %	0 %
Th.5～Th.8	0 %	0 %	0 %	0 %
Th.9～Th. 11	22.6%	0 %	0 %	0 %
Th. 12～L. 1	24.7%	13.4%	2 %	–
L.2～L. 4	4 %	9 %	10 %	–
L. 5～L.7	0 %	0 %	0 %	0 %
S. 1～S. 3	0 %	13.9%	28.7%	59.8%
S. 3～Coc. 1	0 %	0 %	0 %	–

colon, thoracolumbar sensory nerves are derived from the dorsal roots of the spinal segments between TH.9～L.4, and most of them are derived from TH.9～L.1. In transverse colon, they are derived from TH.12～L.4, and most of them from TH. 12～L.1. In descending colon, they are derived from TH.12～L.4 as in transverse colon, but most of them from L.2～L.4.

Few in number, the vagal sensory nerves are distributed only in the ascending colon. The distribution of sacral sensory nerves in the colon begins in the hepatic flexure, gradually increasing in number in the transverse colon, and suddenly become more numerous in the descending colon. Therefore, in the descending colon the sacral sensory nerves are predominant over thoracolumbar sensory nerves.

The ascending, transverse, and descending colon are under control of both sympathetic (thoracolumbar) and parasympathetic (vagal or sacral) sensory nerves. Every part of the colon is clearly under the sensory innervation of many spinal segments. From Table 1, the number of sensory nerves is summarized as follows:

1. In the ascending colon; Thoracolumbar sensory nerves $\geqslant$ vagal sensory nerves
2. In the transverse colon; Thoracolumbar sensory nerves $>$ Sacral sensory nerves
3. In the descending colon; Thoracolumbar sensory nerves $\leqslant$ Sacral sensory nerves

(3) The myelinated nerve fibers in the lig. gastrocolicum.

Extension specimens taken from lig. gastrocolicum were fixed in 10% neutral formol solution and stained with EHRLICH's acid hematoxyline method and BIELSCHOWSKY-SETO's silver impregnation.

In the lig. gastrocolicum, a great number of myelinated nerve fibers were found running from the stomach to the transverse colon. (Fig. 45.) The bundles of these myelinated fibers run generally in contact or parallel with the blood vessels, but sometimes quite separately from blood vessels. A thick bundle contains 5~6 myelinated fibers and a slender one 1~2 myelinated fibers. Sometimes a fiber runs out of a nerve bundle to join the adjacent one. Neither nerve plexus nor ganglia was found there.

The author cut almost all the gastric branches of the vagus at the cardiac region of the stomach. Seven days later, these specimens clearly revealed degenerated myelinated nerves in them. (Fig. 46.) Besides few degenerated myelinated fibers, many nerve fibers were found in normal appearance. Although the present experiments have not covered the transverse colon, these degenerated myelinated nerves may reach down the transverse colon without ending at the lig. gastrocolicum. There were found medium calibered myelinated fibers among the degenerated fibers, too, and they may be vagal sensory nerves. The numerous number of normal myelinated nerves which were found, besides the degenerated nerves after vagotomy, might be identified with the splanchnic sensory nerves.

V. DISCUSSION

In the ascending, transverse, and descending colon of human beings and dogs, the author has successfully detected visceral sensory nerves as well as their endings. Of course, there are autonomic nerve fibers besides autonomic "terminalreticulum" in the colon. When they are cut, the stumps of autonomic nerve fibers often seem to be free endings of nerves. But these autonomic fibers usually become a network in the periphery beyond the intramural plexus of the colon, where the sensory nerves still retain the thick fiber form. Therefore, they are clearly distinguishable from autonomic nervous system. Sometimes they run between or around the crypts of the intestine. But none of them have been found to enter into the crypts. It is not reasonable to consider them as the autonomic nerves which directly control the crypts because the number of these nerve endings in the colon is very small compared with that of the crypts. So, they are different in nature from secretory nerves.

On myelin sheath staining, the author found that these nerves kept the myelin sheaths even in the most peripheral layer where myelinated autonomic fibers may not exist. Following the posterior rhizotomy, including spinal ganglia, these myelinated thick nerves degenerated as far as these peripheral layers. This experiment has disclosed that they originate in the dorsal roots of the spinal cord and come to their endings without interruption of neurons in their course.

Judging from these facts, the free terminated thick nerves in the colon must

be sensory in nature; i. e. they are nothing but the cerebrospinal sensory nerves accompanied by autonomic nerves. The cerebrospinal sensory nerves in the viscera have been physiologically studied by LANGLEY, FÖRSTER, GREVING, CLARK, GAGEL, ISHIKAWA, KUNTZ, RANSON, BILLINGSLEY and other investigators in our clinic. Especially in our clinic, the systematic histological studies by the investigators were done in various regions of the digestive tract; i. e. TANAKA in oesophagus; OTSU in stomach, duodenum, jejunum and sigmoid; INOUE in biliary tract; MAKINO in ileum and cecum; and WANG in sigmoid and rectum. They showed the existence of sensory nerves in these parts by an original method of observation. The results of my experiments in the colon also agree with the opinion of these investigators.

Thus the author has observed sensory nerves in the ascending, transverse, and descening colon where the observation of sensory nerves in detail were unknown.

The distribution of the myelinated sensory fibers is demonstrated as followings: a small number in the ascending colon, fair number in the transverse colon, and very numerous in the descending colon. The medium and large sized myelinated nerves are especially numerous in the descending colon. These are referred to as being sensory in nature by ALLEN, WINDLE, ISHIKAWA, HAMABE, WATANABE, HEINBECKER and TAZAKI. The large sized myelinated nerves are only found in the descending colon. They are not found in the upper parts of the colon.

Concerning the distribution of the sensory endings, the same tendency is demonstrated in the various parts of the colon. In the ascending colon, only a few simple unforked sensory endings were found. In the transverse colon simple bifurcations of the endings began to appear and increased in number. In the descending colon the bifurcated endings suddenly increased in number and arborized endings were found among them. And in the descending colon, many sensory endings were found reaching to the lamina propria mucosae or around the crypts of the intestine.

These facts suggest that the ascending and transvere colon are under almost the same mode of sensory innervation, but it is much different in the descending colon. The developed sensory nerves in the descending colon may play a role in the perception of defecatory stimulation.

Generally, sensory nerve endings are considered to be of specifically complicated shapes and MAX CLARA counted the various specific structures. These shapes of sensory nerve endings were considered to be for the purpose of enlarging the terminal surface.

The author's finding that the sensory nerve endings in the colon are unforked or simple arborized may be contradictory to common belief. But, MAX CLARA also pointed to the arborizing free endings as sensory nerve endings, which receive pain and compressive stimuli. Recently G. WEDDELL, on biostaining and silver impregnation, reported that sensory nerve endings on the skin are generally arborized and free endings rather than any specific shape which can be artefact in the process of specimen preparation. He states that the arborizing free endings only act as receptor of painful sensation on the human skin. The author's findings agree with WEDDELL's opinion.

In the stomach, OTSU assumed that the sensory nerves passed through the muscular layer and AUERBACH'S plexus, after losing their myelin sheaths, bifurcated and ended freely in the mucous membrane. The author found bifurcated nerves keeping their myelin sheaths in the submucous layers of the transverse and descending colon, and often found myelin sheaths in the lamina propria mucosae and between the intestinal crypts. Therefore, the sensory nerves, which the author observed in the colon, lose their myelin sheaths near termination.

FEYRTER reported that the argyrophilic cells existent among the cells of the crypts of the intestine are a receptor of sensory nerves. The argyrophilic cells are always numerously found in the crypts of the colon. The author does not think it reasonable to consider the argyrophilic cells as a receptor of sensory nerves. Because on the silver impregnation, the sensory nerve endings were not observed to be directly or indirectly connected with the argyrophilic cells.

The author found abnormally deformed sensory nerves in the ascending colon of a case of CROHN'S disease. Also he found the same sensory nerves in considerable number in the dilated portion of congenital megacolon. These findings correspond with the appearance of degenerated sensory nerves following experimental posterior rhizotomy. (Fig. 40, 41.) Thus it is considered that in CROHN'S disease sensory nerves are gradually degenerated from their peripheral sides by inflammation. SPIELMYER reported that these abnormally shaped nerve fibers were nothing but a degeneration of axis cylinder. Recently O. HAFERKAMP reported that such clubbed or ampullar deformed axis cylinder in the tunica submucosa of the rectum of a proctitis case was a degneration due to inflammation.

In experiments on dogs, no sensory nerve derived from the ventral roots of the spinal cord was proved to exist in any part of the colon. But after posterior rhizotomy of the thoracolumbar cord, degeneration of both the myelin sheath and axis cylinder was observed in every part of the ascending, the transverse, and the descending colon. Sensory nerves, derived from the dorsal roots of the sacral marrow, were proved to start at the region of hepatic flexure of the transverse colon, and suddenly increased in number in the descending colon. This shows that most of the sensory nerves in the descending colon are sacral sensory nerves. These numerous sacral sensory nerves are considered to receive the defecating stimulus in the descending colon. S. OKINAKA maintained that many myelinated nerves were contained in the S.2 nerve; and he stated that most of them might be spinal parasympathetic afferents. In the author's experiments, no degenerated nerve fiber was found after posterior rhizotomy of S.3~Coc.1. Therefore, this finding suggests that the sacral sensory nerves in the tranverse and descending colon are derived from the dorsal roots of S.1~S.2., and it is in accordance with S. OKINAKA'S opinion. Sensory nerves, derived from the vagus, were recognized only in the ascending colon of dogs. According to MAKINO, no vagal sensory nerve was found in jejunum, ileum and cecum, but in the ascending colon the author found them a very few, and thoracolumbar sensory nerves (sympathetic) were more dominant than the vagal sensory nerves. On

the contrary, in the descending colon, the number of sacral sensory nerves (parasympathetic) was more dominant than thoracolumbar sensory nerves. Thus, histologically it is confirmed that the colon is under control of dual sensory innervation, and this corresponds with the results of KIMURA's physiological experimentation.

In the dog, the vagal afferent nerves were found only in the ascending colon. But, in the human being, the vagal afferent nerves are likely to be found also in the transverse colon. The author found numerous nerve bundles consisting of myelinated nerve fibers of various sizes in the lig. gastrocolicum running from the stomach down the transverse colon. The author also observed degeneration of medium sized myelinated nerve fibers in the above mentioned nerve bundles following vagotomy in the cardiac part of the stomach. Many authors state that the medium and large sized myelinated nerves in the vagus are afferents. It is also suggested that there is a nervous control by the vagus on the colon, coming from the gastric branches of the vagus via lig. gastrocolicum. This pathway was discovered by the author and considered as a newly found route for gastrocolic reflex.

In the present experimentation the author has studied the myelinated sensory nerves originating from the cells of spinal ganglia or passing through the vagus. They are morphologically quite different from the autonomic nervous terminations such as "the nervous praeterminal and terminalrecticulum" (STÖHR, REISER), "the sympathetic ground plexus" (BOEKE), "the vegetative end net" (FEYRTER), "the neurovegetative preterminal plexus" (SUNDER-PLASSMANN), "the distal nervous syncitium" (JABONERO), "the plasmodial nervous terminal network" (R. GREVING) or the "Schlingenterritorium" (winding territory) (STÖHR). These belong to the autonomic nerve system and do not show degeneration following vagotomy and posterior rhizotomy. However, the author does not deny the existence of sensory nerves consisting of non-myelinated nerve fibers. They may be found among the visceral nerves which are presently considered as autonomic nerves. "Schlingenterritorien" were found in the submucous layer of digestive tract and in other organs by many authors, and it was interpreted as an afferent apparatus by STÖHR. The author found many "Schlingenterritorien" in the submucous layers of the ascending, transverse, and descending colon. (Fig. 47, 48.) It is impossible to deny the existence of a sensory apparatus in the autonomic nerve system, but it appears still difficult to confirm that winding territory (Schlingenterritorium) is sensory in nature only from a morphological view. They may be either an adaptive form of nervous system to the elasticity of hollow organs, or an artefact due to the shrinking during the formol fixation. Recently R. GREVING and V. JABONERO gave the same interpretation to the winding territory.

VI. SUMMARY AND CONCLUSION

Using specimens of the ascending, transverse, and descending colon of human beings and dogs, sensory nerves and their endings have been studied, and systematic observations of their sensory innervation by means of secondary degeneration have been made with the following results:

1) Sensory nerve endings with unforked or simple arborized free endings are found in the ascending, transverse, and descending colon of human beings and dogs.

2) These sensory endings are usually found in the lamina propria mucosae and the lamina muscularis mucosae, and some in the submucous layer, however rarely in the muscular layer.

3) The sensory nerve endings in the colon are sharpened at the points, never clubbed or nodular in shape. No specific sensory receptor is found in the colon.

4) The sensory nerve endings are small in number and all unforked in the ascending colon; they increase in number in the transverse colon showing simple forked endings; and they become more numerous in the descending colon showing arborized endings. These findings show an increased sensory innervation in the descending colon near the anus.

5) In the ascending colon of a case of CROHN's disease, the abnormally deformed degenerated sensory nerve fibers were observed.

6) Sensory nerves in the ascending, transverse, and descending colon keep myelin sheaths in the periphery. Myelin sheaths are found sometimes even between the crypts of the colon and beneath the epithel cells.

7) The sensory nerves in the colon are mostly 3.3～4.0μ thick (medium sized) myelinated nerves.

8) The sensory nerves starting from the spinal cord have their cell bodies in the ganglia of the dorsal roots of the spinal cord. They do not change neurons on the way to their terminations.

9) In the ascending colon of the dog, although very small in number, sensory nerves come from the vagus.

10) In the dog, sensory nerves, derived from the dorsal roots of sacral marrow are distributed upward up to the region of the hepatic flexure of the transverse colon. The more distal portion of the colon, the more the number of sacral sensory nerves are found.

11) The ascending, the transverse, and the descending colon are under control of the dual sensory innervation. In the ascending colon of the dog, sensory nerves arise from the dorsal roots of the spinal segments between TH.9～L.4 as well as from the vagus, and the former maintains predominance over the latter. In the transverse colon of the dog, sensory nerves arise from TH.12～L.4 as well as from S.1～S.2, the former is rather more dominant than the latter in number. In the descending colon of the dog, sensory nerves arise from TH.12～L 4 and S.1～S 2, and the latter are predominant than over the former.

12) In the human being, the author found numerous nerve bundles consisting of myelinated fibers in the lig. gastrocolicum running from the stomach down the transverse colon. Following vagotomy, medium seized myelinated nerve fibers in these nerve bundles were degenerated. It suggests that a part of the sensory nerves in the gastric branches of the vagus reach the transverse colon via the lig. gastrocolicum.

13) The author often found winding territories (Schlingenterritorien) in the submucous layer of the ascending, transverse, and descending colon. But they are quite different from the sensory nerve endings which were under the present observation. It is doubtful that winding territory is a sensory apparatus.

14) In the present study, the sensory nerve endings are visualized, so far as the present method is used, as simple bifurcated free endings. Even in the extreme peripheral layer, they keep their myelin sheaths. Their appearances are quite different from autonomic nervous terminations described by STÖHR or by JABONERO.

I am much indebted to Assistant Prof. Dr. CHUJI KIMURA of our clinic for his constant help throughout my study.

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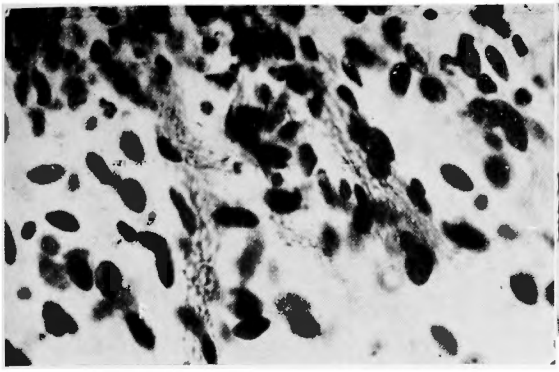

Fig. 1. Autonomic "terminalreticulum" in the submucous layer and the tunica muscularis mucosae of a human T-colon. B-S ×800

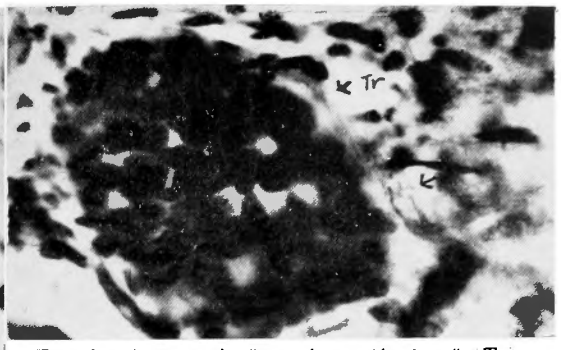

Fig. 2. Autonomic "terminalreticulum" (Tr) around the crypt in the mucous membrane of the A-colon of a dog. B-S ×1000

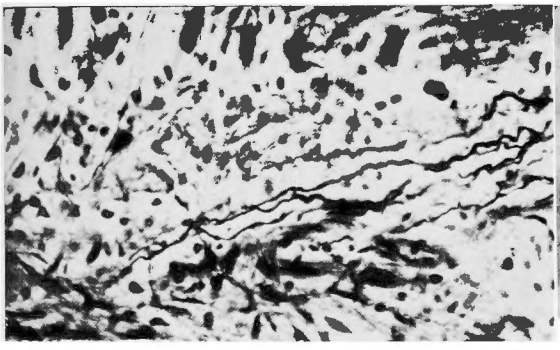

Fig. 3. Sensory nerve fibers passing through Auerbach's plexus of a human T-colon. B-S ×300

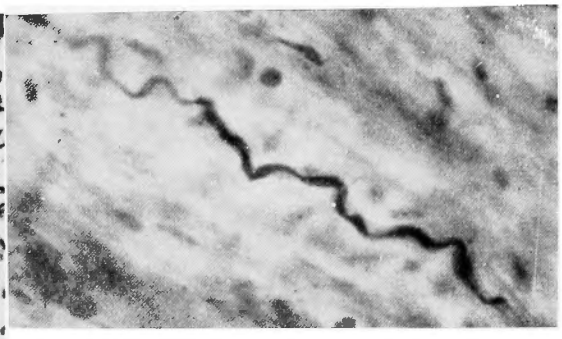

Fig. 4. A sensory nerve fiber in the muscular layer of a human T-colon. B-S ×600

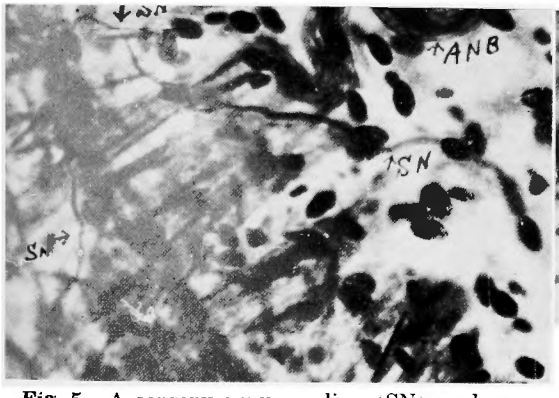

Fig. 5. A sensory nerve ending (SN) and an autonomic nerve bundle (ANS) in the tunica muscularis mucosae of the T-colon of a dog. B-S ×600

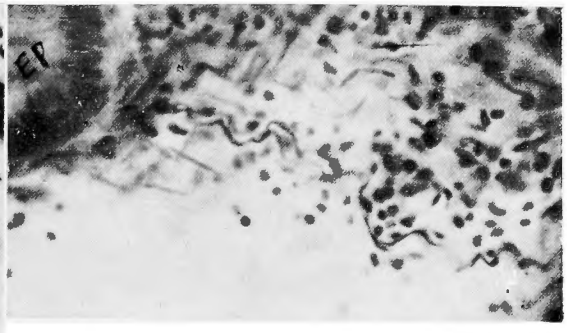

Fig. 6. Sensory nerve endings in the submucous layer and the mucous membrane of a human T-colon. B-Suz. ×400

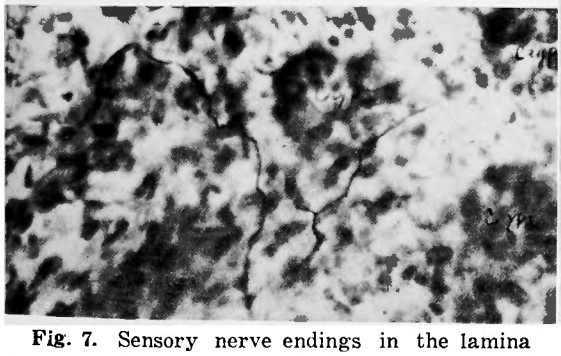

Fig. 7. Sensory nerve endings in the lamina propria mucosae of a human T-colon. B-S. ×400

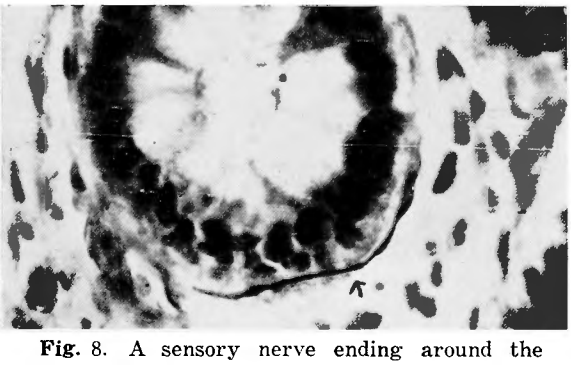

Fig. 8. A sensory nerve ending around the crypt in the mucous membrane of a human D-colon. B-S. ×800

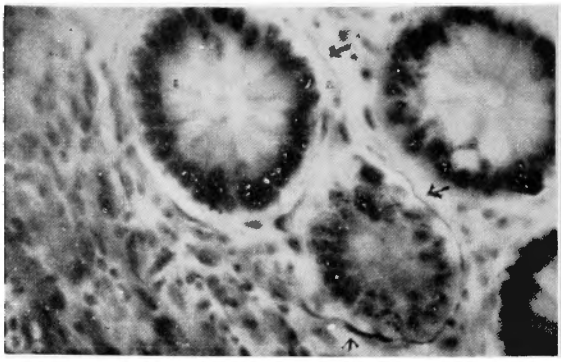

Fig. 9. A sensory nerve ending around the crypts in the mucous membrane of a human D-colon. B-S. ×400

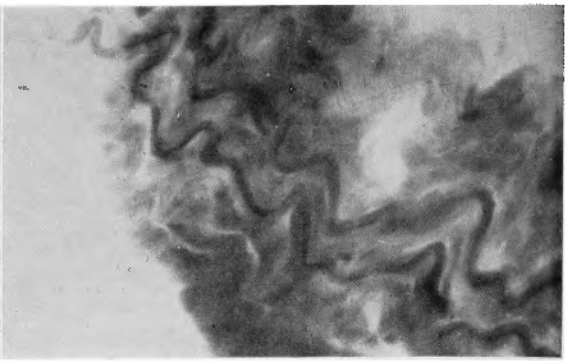

Fig. 10. Myelinated nerve fibers passing through Auerbach's plexus of a human T-colon. E. ×600

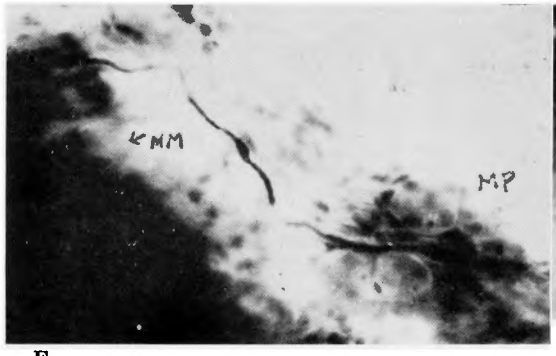

Fig. 11. A myelinated nerve fiber entering the mucous membrane (MM) through Meissner's plexus(MP) of the T-colon of a dog. E. ×400

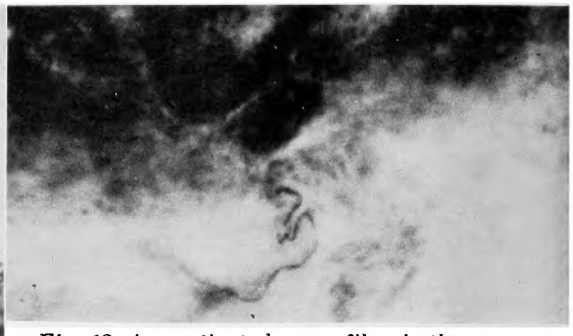

Fig. 12. A myelinated nerve fiber in the mucous membrane of the D-colon of a dog E. ×300

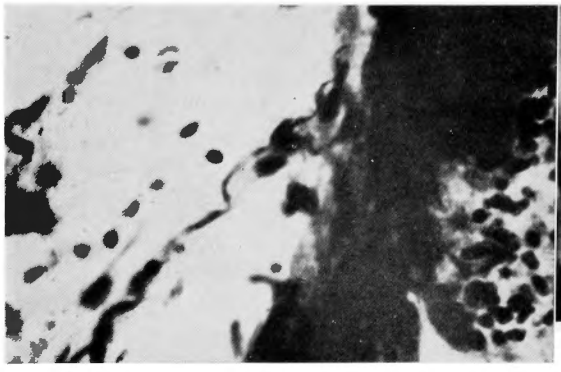

Fig. 13. A sensory nerve ending in the submucous layer of a human A-colon. B-S. ×400

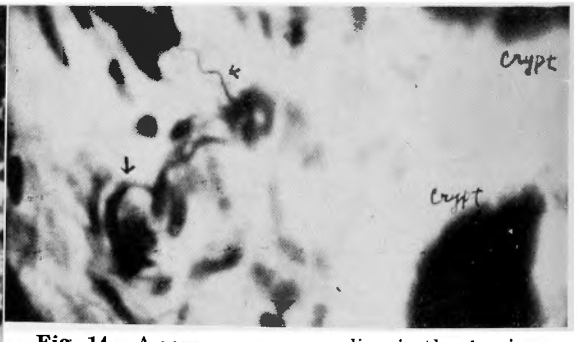

Fig. 14. A sensory nerve ending in the lamina propria mucosae of a human A-colon. B-Suz. ×600

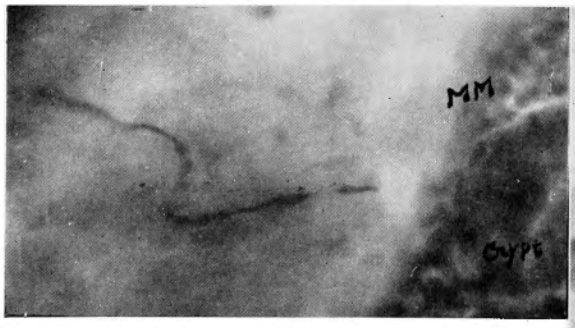

Fig. 15. A myelinated nerve fiber entering the mucous membrane (MM) of the A-colon of a dog. E. ×400

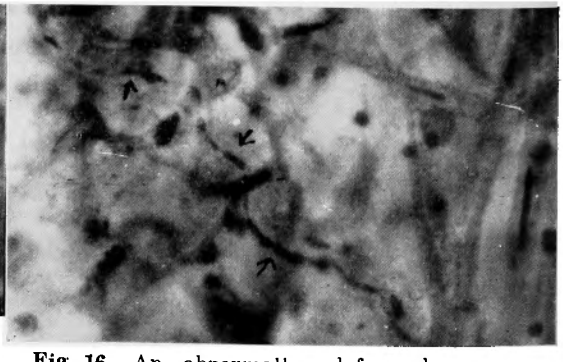

Fig. 16. An abnormally deformed sensory nerve fiber in the tunica muscularis mucosae of the A-colon of Crohn's disease. B-S. ×600

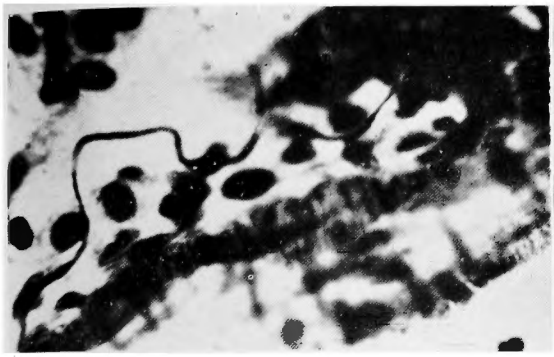

Fig. 17. A sensory nerve fiber tangled the blood vessel in the submucous layer of a human T-colon. B-S. ×600

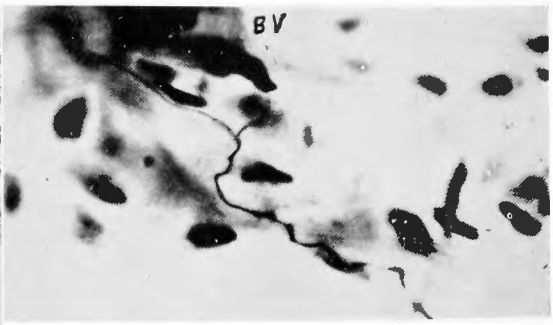

Fig. 18. A bifurcated sensory nerve ending at the wall of the blood vessel (BV) in the submucous membrane of a human T-colon. B-S. ×800

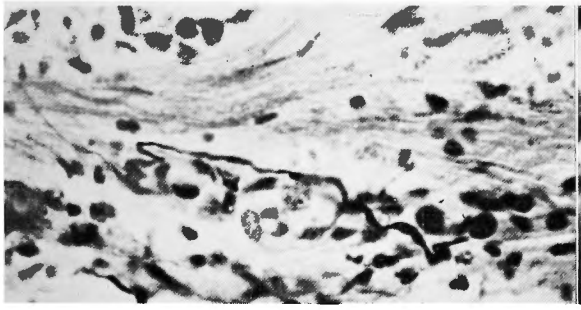

Fig. 19. A sensory nerve ending in the tunica muscularis mucosae of a human T-colon. B-Suz. ×400

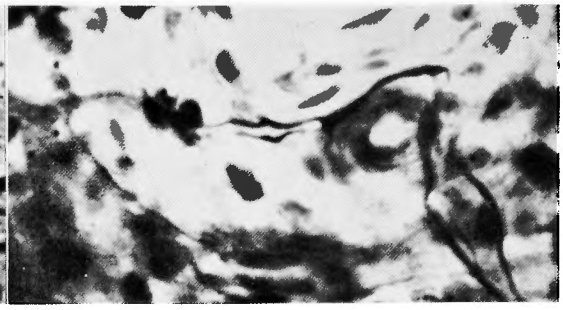

Fig. 20. A bifurcated sensory nerve ending in the tunica muscularis mucosae of a human T-colon. B-S. ×600

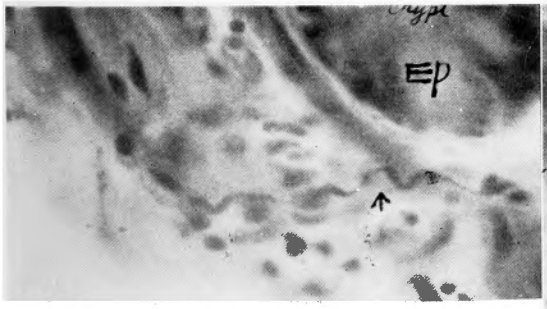

Fig. 21. A sensory nerve ending in the mucous membrane of a human T-colon. B-Suz. ×600

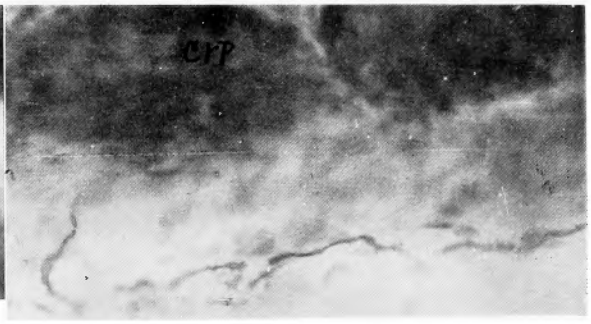

Fig. 22. A myelinated nerve fiber in the mucous membrane of the T-colon of a dog. E. ×400

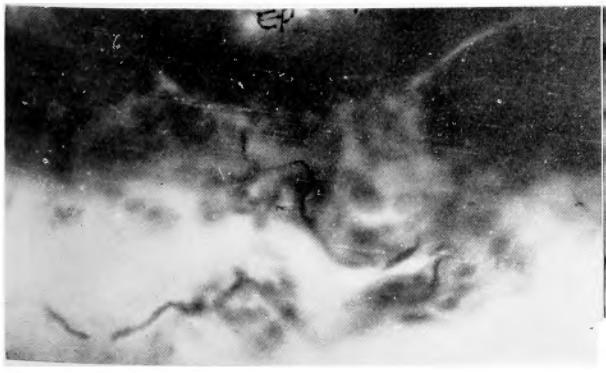

Fig. 23. A myelinated nerve fiber in the mucous membrane of the T-colon of a dog. E. ×400

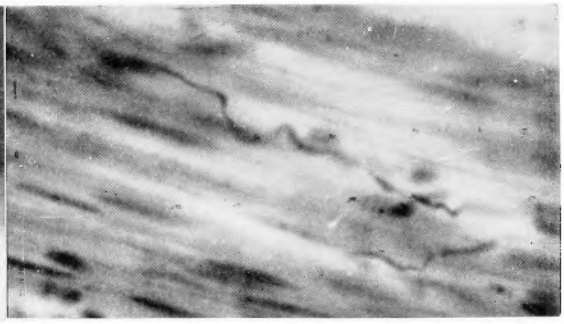

Fig. 24. A sensory nerve ending in the muscular layer of a human D-colon. B-Suz. ×600

Fig. 25. A bifurcated sensory nerve ending at the wall of the blood vessel (BV) in the submucous layer of a human D-colon. B-S. ×800

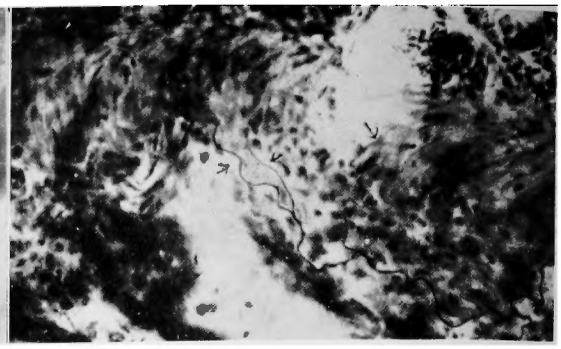

Fig. 26. An arborized sensory nerve ending in the submucous layer and the tunica muscularis mucosae of the D-colon of a dog. B-S. ×300

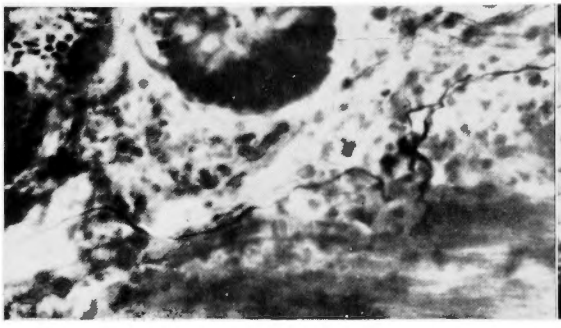

Fig. 27. Sensory nerve endings in the mucous membrane of a human D-colon. B-S. ×300

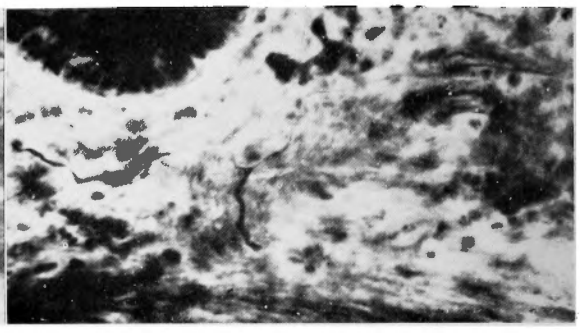

Fig. 28. A bifurcated sensory nerve ending in the mucous membrane of a human D-colon. B-S. ×400

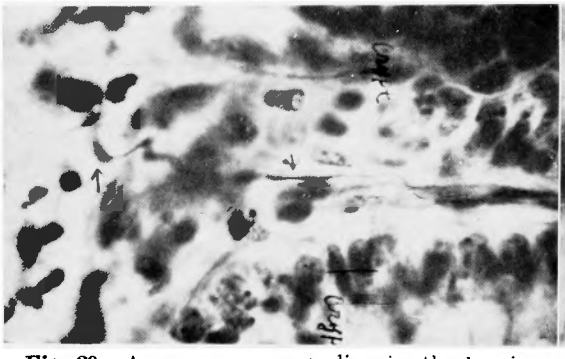

Fig. 29. A sensory nerve ending in the longitudinal section of the mucous membrane of a human D-colon. B-S. ×800

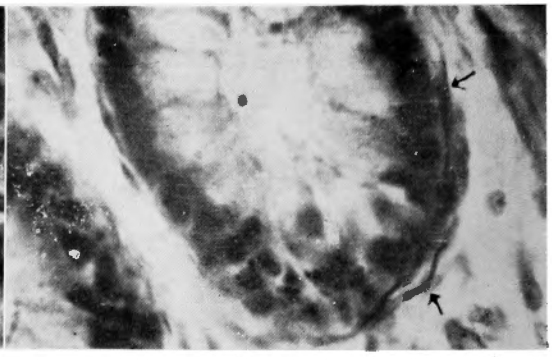

Fig. 30. A bifurcated sensory nerve ending surrounding the crypt in the mucous membrane of a human D-colon. B-S. ×800

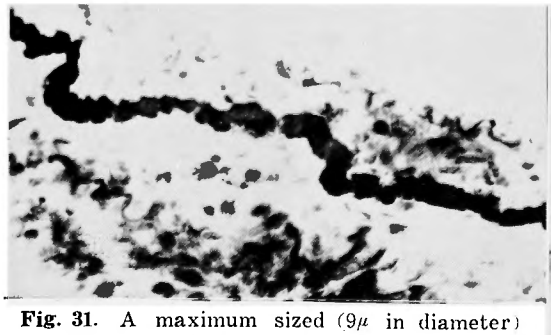

Fig. 31. A maximum sized (9μ in diameter) myelinated nerve in the D-colon of a dog. E. ×400

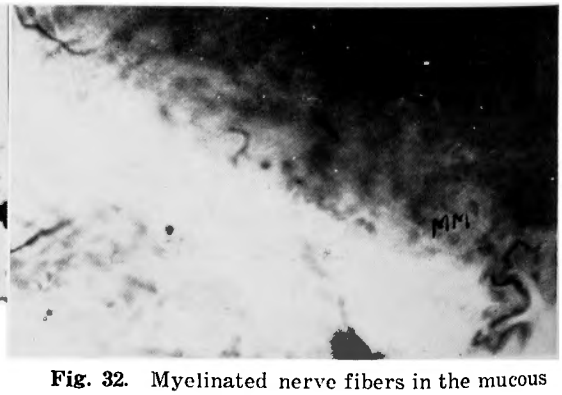

Fig. 32. Myelinated nerve fibers in the mucous membrane of the D-colon of a dog. E. ×300

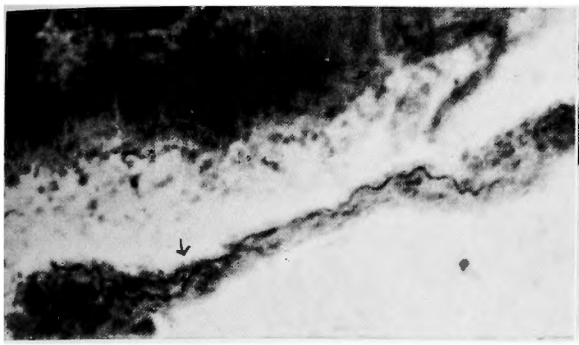

Fig. 33. A bifurcated myelinated nerve fiber in the submucous layer of the D-colon of a dog. E. ×200

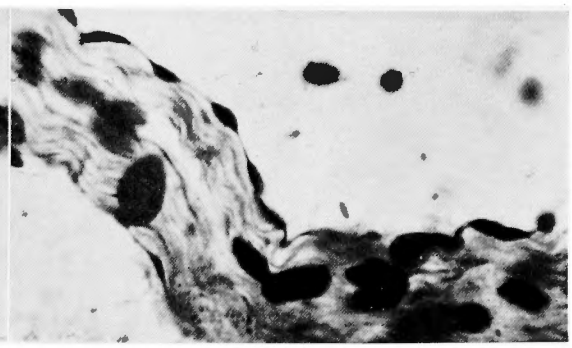

Fig. 34. An abnormally deformed (degenerated) sensory nerve fiber in the submucous layer of the D-colon of a dog following posterior rhizotomy (TH.13~L.4). E. ×800

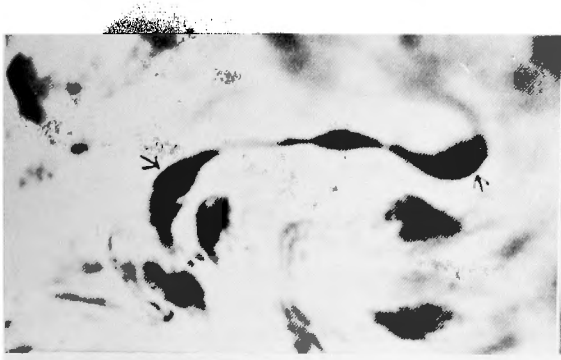

Fig. 35. An abnormally deformed (degenerated) sensory nerve fiber in the submucous layer of the D-colon of a dog following posterior rhizotomy (S_1~S_3). B-S. ×1000

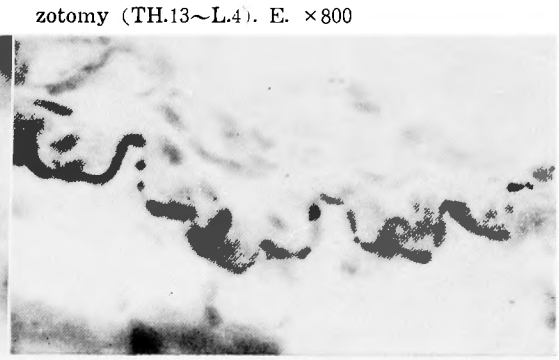

Fig. 36. A degenerated myelinated nerve fiber in the submucous layer of the A-colon of a dog following posterior rhizotomy (TH.9~TH.12). E. ×600

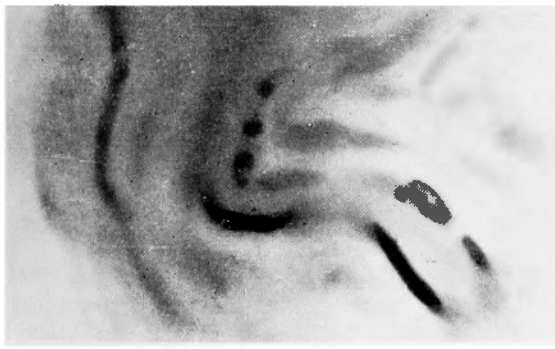

Fig. 37. A degenerated myelinated fiber in the submucous layer of the T-colon of a dog following posterior rhizotomy (TH.13~L.4). E. ×600

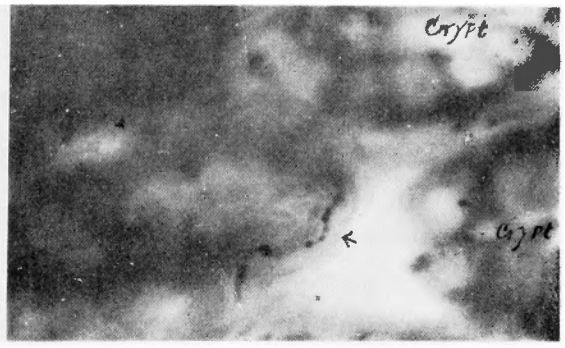

Fig. 38. A degenerated myelinated nerve fiber between the crypts in the mucous membrane of the A-colon of a dog following posterior rhizotomy (TH.9~TH.12). E. ×400

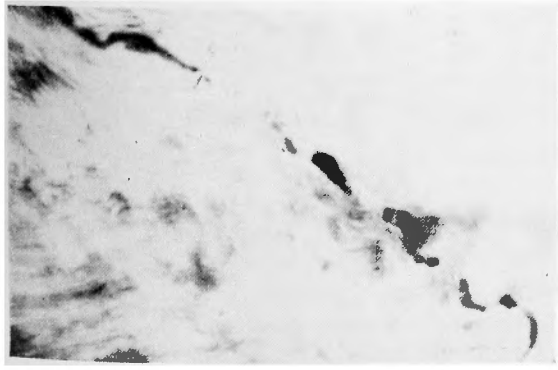

Fig. 39. A degenerated medium sized myelinated nerve in the submucous layer of the D-colon of a dog following posterior rhizotomy (S_1~S_3). E. ×400

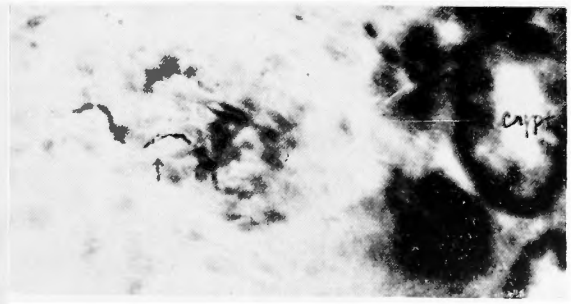

Fig. 40. A degenerated myelinated nerve in the tunica muscularis mucosae of the D-Colon of a dog following posterior rhizotomy (S_1~S_3). E. ×300

Fig. 41. A degenerated medium sized myelinated fiber in Auerbach's plexus of the A-colon of a dog following vagotomy. E. ×400

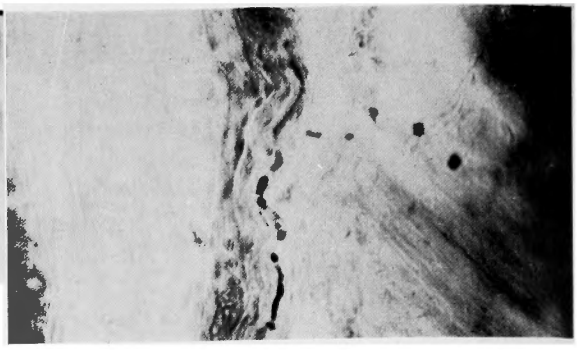

Fig. 42. A degenerated myelinated nerve in the submucous layer of the A-colon of a dog following vagotomy. E. ×300

Fig. 43. Degenerated axis cylinders in the submucous layer of the T-colon of a dog following posterior rhizotomy (TH.13~L4). B-S. ×400

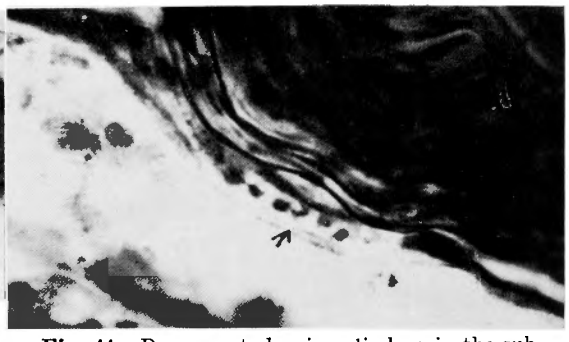

Fig. 44. Degenerated axis cylinders in the submucous layer of the D-colon of a dog following posterior rhizotomy (S_1~S_3). B-S. ×600

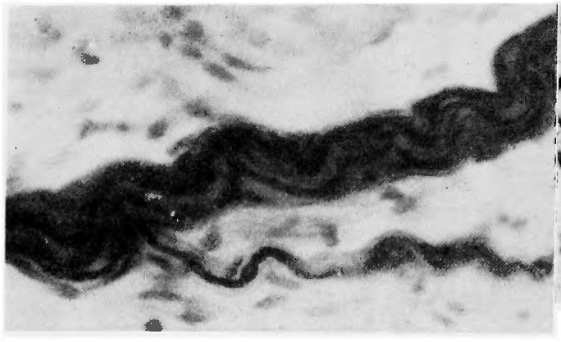

Fig. 45. Myelinated nerve fibers in the lig. gastrocolicum of the human being. E. ×400

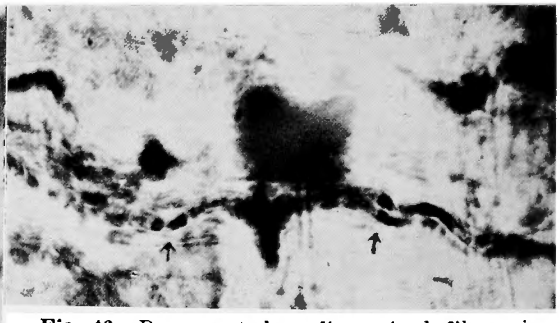

Fig. 46. Degenerated medium sized fibers in the lig. gastrocolicum of the human being following vagotomy. E. ×400

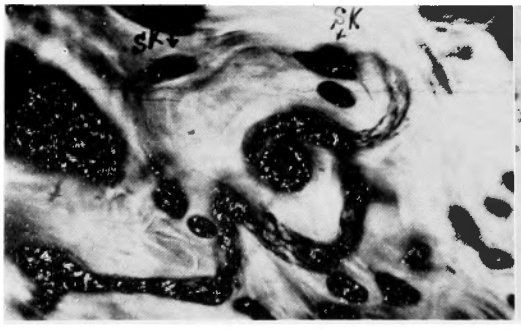

Fig. 47. Winding territory (Schlingenterritorium) in the submucous layer of the T-colon of a dog. B-S. ×900

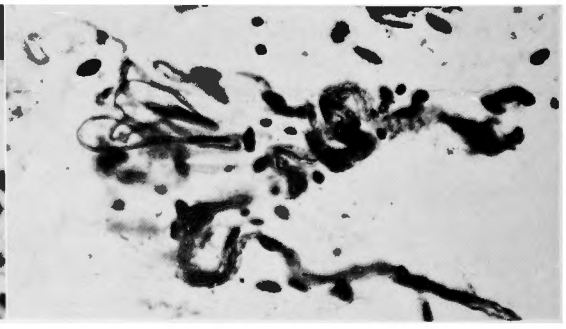

Fig. 48. Winding territory (Schlingenterritorium) in the submucous layer of a human A-colon. B-S. ×400

(Ref. continued)

1923., Zeitschrift für Zellforsch. u. Mikr. Anatomie, **12**; 129, 139, 1931. 40) Seto, H.: Progress of Medicine (in Japanese), **5**; 225, 1949., The Tohoku Journal of Experimental Medicine, **54**; No. 1, 1951., Kaibogaku Zasshi, **29**; 2, 1954., The Tohoku Journal of Experimental Med., **26**; 3, 1940. 41) Sekigawa, J.: Jiuzenkai Zasshi, **41**; 2442, 1936. 42) Seki, M.: Soshikigaku (Histologie), Kyorin Shoin, Tokyo, 1954. 43) Suzuki, K.: Noshinkeiryoiki, Vol. 5, No. 2, (Brain-Researches, Vol. 13), 184, 1952. 44) Sunder-Plassmann, P.: Deutsche Zeitschrift für Chirurgie, **224**; 736, 1947. 45) Sheehan, D.: Brain, **55**; 493, 1932. 46) Spielmeyer, W.: Histopathologie des Nervensystem, 1922. 47) Sada.: Psych. et Neur. Japonica, **46**; 1943. 48) Sugamata, G.: Kaibogaku Zasshi (Acta Anatomica Nipponica-in Japanese), Vol. 27, No. 3, 1952. 49) Takino, M.: The Path-Physiology of the Human Autonomic Nervous System (Zintai Ziritsu Shinkei No Byotai Seiri, in Japanese), Tokyo, 1950. 50) Tazaki, K.: The Japanese Journal of Physiology (Nippon Seirishi), **11**; 1949. 51) Takayasu, T.: Tokyo Igakkai Zasshi (Journal of Tokyo Med. Soc. -in Japanese), **48**; 837, 1955, 1934., **49**; No.7, 1935. 52) Tanaka, N.: Arch. f. Jap. Chir. **22**; 439, 1953. 53) Weddell, G. and Sinclair, D. C.: Acta Neuroveg., **7**; 135, 1953. 54) Weddell, G.: The Anatomical Record, Vol. **118**; No. 4, 1954., J. Anat. **75**; 346, 1954. 55) Watanabe, Y.: Arch. f. Jap. Chir. **23**; 1954. 56) Wang, W. F.: Arch. f. Jap. Chir. **24**; 567, 1955. 57) White, J. C., Smithwick, R. H. and Simeone, F. A.: The Autonomic Nervous System, 3rd ed., 1952. 58) Windle, W. F.: J. Comp. Neurol., **40**; 229, 1926., **41**; 453, 1926., **43**; 347, 1927. 59) Yagita, M.: Arch. f. Jap. Chir. **23**; 569, 1951. 60) Zimmermann, R.: Mitteilungen aus den Grenzgebienten der Medizin und Chirurgie, **20**; 445, 1909.

EXPLANATION OF FIGURES

1) A—colon……Ascending colon
2) T—colon……Transverse colon
3) D—colon……Descending colon
4) B-S…… Seto's Method (Seto's modification of Bielschowsky's silver impregnation)
5) B-Suz…… Suzuki's Method (Suzuki's Modification of Bielschowsky's silver impregnation)
6) E…… Ehrlich's acid haematoxyline method
7) Letters in the figures indicates,
   Ep.……Epithelium
   Crp…… Crypt of the intestine
   S. K.……Schwann's Nucleus
   MP.…… Meissner's plexus
   MM.…… Mucous membrane

和 文 抄 録

上行結腸，横行結腸及び下行結腸の知覚神経の組織学的研究

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李 仁 敏

Bielschowsky 氏神経鍍銀法の瀬戸氏変法，鈴木氏変法及び Ehrlich 氏神経髄鞘染色法を用い，人及び犬の新鮮なる上行結腸，横行結腸及び下行結腸の標本に於て知覚神経並にその終末の形態及び分布を検索し更に迷走神経，脊髄前根（TH.12～L.2, S.1～S.3）及び脊髄後根（TH.5～TH.8, TH.9～TH.12, TH.13～～L.4, L.5～L.7, S.1～S.3, S.3～Coc.1）を実験的に切断せる犬の上行結腸，横行結腸及び下行結腸組織内の末梢神経の二次的変性を追述し，之等の結果より上行，横行及び下行結腸の知覚神経に就て次の結論を得た．

1) 人及び犬の上行，横行及び下行結腸に於て非分岐性並に単純性樹枝状の遊離性知覚神経終末が発見される．

2) 之等の知覚神経終末は主として粘膜固有層並に粘膜筋層に発見され，一部は粘膜下層に，甚だ稀には筋層に発見される．

3) 上行，横行及下行結腸の知覚神経終末の尖端は尖鋭状を呈し，棍棒状又は小結節状を呈しない．又特殊知覚神経終末は発見されない．

4) 知覚神経終末は上行結腸に於てその数が少く，すべて非分岐性知覚神経終末を示すが，横行結腸に於てはその数を増加し，非分岐性並に単純性分岐性知覚神経終末を示し，更に下行結腸に於ては急激に増加し形状も稍々複雑となり樹枝状のものも発見される．之等の所見は肛門に近い下行結腸になる程知覚神経支配の増加することを示すものである．

5) Crohn's disease の上行結腸に於て異常形の変性知覚神経線維が発見された．

6) 上行，横行及び下行結腸の知覚神経は最末梢層に於てその終末の近くまで髄鞘を有し，時には粘膜の腸陰窩の間又は上皮下に髄鞘が発見される．

7) 上行，横行及び下行結腸の知覚神経は大部分 3.3μ～4.0μ の太さ（中径）の有髄神経である．

8) 脊髄から来る上行，横行及び下行結腸の知覚神経（脊髄性知覚神経）は脊髄後根神経節にその細胞体を有し，終末に到る迄神経元を交替しない．

9) 迷走神経を通る知覚神経（迷走性知覚神経）は上行結腸にのみごく少数発見される．

10) 犬に於ては，仙髄後根を通る知覚神経(仙髄性知覚神経)は上方は横行結腸肝彎曲部から分布し始め，それより下方肛門に近くなればなる程急激にその数を増加する．

11) 上行，横行及下行結腸は2重知覚神経支配下にある．犬の上行結腸の知覚神経は，（TH.9～L.4）の脊髄後根と迷走神経から由来し，胸腰髄後根性の知覚神経支配が迷走性のものより遙かに優性である．横行結腸は（TH.12～L.4）と（S.1～S.2）から由来し，胸腰髄後根性知覚神経支配が仙髄後根性のものより稍々優勢である．下行結腸では（TH.12～L.4）と（S.1～S.2）から由来し，仙髄後根性知覚神経支配が胸腰髄後根性のものより圧倒的に優勢である．

12) 人間の胃結腸靱帯には胃から横行結腸に走る多数の有髄神経束が発見され，而も迷走神経切断によりそれらの神経線維束中の中径の有髄神経線維に変性を来すものが発見される．之は迷走神経胃枝に含まれる知覚神経の一部がこの胃結腸靱帯を経て胃から横行結腸に達するものと考えられる．

13) 上行，横行及び下行結腸の粘膜下層には屢々 "Schlingenterritorien" が見出されるが，この研究に於ける上記の知覚神経はこれとは全く別箇のものである．又 "Schlingenterritorien" は知覚感受装置であると言われているが疑わしい．

14) この研究に於て吾々の現在の方法を用いる限りに於ては知覚神経終末は単純性分岐性遊離性終末として観察され，最末梢層に於ても尚髄鞘を有し Stoehr 或は Jabonero によつて記載された自律神経終末とは全くその形態を異にしている．

Bowel Function after Colectomy for Cancer, Polyp and Diverticulitis

R. C. Lillehei and O. H. Wangensteen J. A. M. A., **159**; 163, 1955.

結腸癌，Polyp，憩室炎の患者に対し，全結腸切除術，亜全結腸切除術を行い，術後の腹部内臓機能に就き検討した．本報告の対象とした患者は総数73名で，その観察期間は1946年1月から1954年4月迄である．又術式としては Closed end to end single row anastmosis を行つた．その結果，

1) 結腸癌の治癒率を上昇させるためには，全結腸切除術又は悪全結腸切除術の施行が望ましい．

2) 本切除術を施行するに当り，回腸を全長に亘り残存せしめる時は勿論，少くとも盲腸部より30cm 口側部以上の回腸を残存せしめる限り，術後便通及び大便の性状は正常である．（井田喜三抄訳）