A HISTOLOGICAL STUDY OF SENSORY NERVES IN THE BILIARY TRACT

by

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I INTRODUCTION

It is clinically evident that disease of the biliary tract often causes abdominal pain. CHUJI KIMURA (Assist. Prof. of our clinic) has proved the sensitivity of the biliary tract by his physiological experiments. According to the results of his study, biliary pain is observed usually as epigastric pain and sometimes as right hypochondriac pain, when the biliary tract is stimulated mechanically or with KIMURA's Acetylcholine Method. T. MAKI and many other investigators have also reported the experimental results of studies on biliary pain in human beings. According to V. L. SCHRAEGER and A. C. IVY, biliary pain is mediated mostly by the right splanchnic nerve. But, from the anatomical point of view, the sensitivity of the biliary tract has not yet been clearly proved.

It is certain that the biliary tract is innervated by the autonomic nervous system, but the peripheral structures of the autonomic nerves have not been known definitely, and many different findings have been reported concerning them. P. STOEHR, JR., and K. A. REISER have concluded: "The autonomic nerves form a fine, closed, and reticulated structure (Praeterminal- und Terminalreticulum) in the periphery without distinction between the sympathetic and parasympathetic systems and they never terminate as free endings." J. BOEKE, P. SUNDERPLASMANN, F. FEYRTER,

J. JABONERO and others have supported the existence of the "Periterminalreticulum". According to them, the "Periterminalreticulum" is found around the "Terminalreticulum" as a finer meshwork and terminates in the end-organ or in the cell.

In agreement with STOEHR's theory, H. SETO (Prof. of anatomy : TOHOKU University) insists that the nerves which terminate freely in the periphery without forming the "Praeterminal- or Terminalreticulum" are sensory nerves, and that these sensory nerves can be easily differentiated from the autonomic nerves by their thickness. H. SETO has reported many sensory nerve endings (SETO) in the alimentary canal (mouth, esophagus, stomach, rectum and anus). But he has recognized no sensory nerve ending in the biliary tract, and no other investigator has reported definite sensory terminations in the biliary tract.

These findings written above suggest that sensory nerve endings must be found also in the biliary tract. Therefore, I searched for sensory nerve endings in the biliary tract, and attempted to confirm them as sensory nerves not only from the standpoint of STOEHR and SETO's theory but also from that of LANGLEY's neuron theory. I also tried to clarify the course of the sensory innervation of the biliary tract by systematic observations.

II MATERIALS AND METHODS

As the post-mortem changes in the biliary tract spread very rapidly, it is very difficult to stain the nervous tissue in the specimens taken at autopsy. So, I used only fresh specimens taken from the gall bladder and the cystic duct which were resected operatively. They were fixed in 10% neutral formol solution immediately after excision. In order to observe normal nervous tissue, I made the preparations only from specimens that contained relatively few pathological changes. Specimens which contained advanced inflammatory changes or neoplasms were not used. After fixation for 6 months or more, the specimens were frozen, sliced in thickness of $35 - 45\,\mu$, and then stained. Specimens taken from dogs were examined by the same method.

Dogs were used as experimantal animals and the degenerated nerve fibers in the biliary tract were examined after operation. Operations were carried out on the dorsal roots of the spinal cord, the vagus nerve, and the phrenic nerve. All the dogs were operated under general anesthesia with the injection of isomytal-sodium, and thoracotomy was performed under positive pressure breathing by inserting the gas tube in the trachea.

The axis cylinder of the nerve was stained with SETO's modification of BIELSCHOWSKY's silver impregnating method (SETO's Method) and EHRLICH's acid hematoxylin method was used to observe the myelin sheath.

SETO's Method

The specimens, which have been cut with 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, being protected from light, for 24 — 48 hours,
3, washed in distilled water for 20 — 30 seconds,
4, put into 20% neutral formol solution,
This solution must be made by diluting the mother neutral formol only with running water, and placed in 4 — 5 plates. The specimens are transferred to these plates one by one until the white precipitation disappears,
5, washed with running water for 30 — 50 seconds,
6, placed on filter paper to blot up the water,
7, put into warm ammoniacal silver solution for about 10 minutes,
8, washed with distilled water twice,
9, placed in 0.05 — 0.1 % gold chloride solution for 3 — 4 hours,
10, placed in 20% sodium thiosulfate solution until the specimens are colored reddish brown,
11, washed in distilled water,
12, dehydrated and mounted.

III SENSORY NERVE ENDINGS IN THE BILIARY TRACT

a) Gall bladder and cystic duct

The "Praeterminal- and Terminalreticulum" is widely distributed through all tissues of the gall bladder and the cystic duct, and especially densely over the muscle layer and in the mucous membrane. This wide-spread distribution of the "Praeterminal- and Terminalreticulum" proves the abundant autonomic innervation of the biliary tract. (Figs. 1, and 2.)

Nerve cells are found between the muscle fibers and in the mucous membrane, as solitary cells or forming a nerve plexus consisting of several nerve cells. But, on the whole, nerve cells are few in the gall bladder and in the cystic duct, and the nerve plexus is not so typical as the myenteric plexus found in the intestines.

In the wall of the gall bladder, relatively thick nerve fibers are found which terminate freely under the mucous membrane separately from the autonomic nerve fibers. In agreement with Prof. H. SETO, I decided these nerves must be sensory nerve endings (SETO). The sensory nerves (SETO) in the gall bladder are thick and wavy nerve fibers that can be traced through the muscle, sometimes accompanying thin nerve fibers, and they never form a network or anastomosis. These thick nerve fibers have no connection with the nerve cells or the "Terminalreticlum", and they enter the mucous membrane growing thinner gradually to terminate freely beneath the epithelium. The sensory nerve endings are few in number; they are especially few in the fundus and in the body of the gall bladder, but a few endings are found in the neck. The sensory nerves terminate in wavy or slightly winding endings sometimes with a few simple branches; they are not tangled endings. (Figs. 3, 4, 5, 6, 7, and 8.) Neither a termination with complicated structure nor a specific end-apparatus can be found.

Sensory nerve endings are found also in the cytic duct, and their number is a little larger than in the gall bladder, and terminate freely in the mucous membrane. The sensory nerve endings in the cystic duct sometimes approach the cystic glands and can be traced around the glands, but they never enter the glands themselves. (Figs. 9, 10, 11, and 12.)

In the human gall bladder, very few myelinated nerve fibers are found. These myelinated nerve fibers are traced from the serous or subserous tissue along or through the muscle and lose their myelin sheathes under the mucous membrane. In the cystic duct, the number of myelinated nerve fibers is a little larger than in the gall bladder. No connection is found between the myelinated nerve fibers and the nerve cells in the biliary wall.

In the gall bladder and the cystic duct of dogs, the wide-spread distribution of the "Terminalreticulum" is found as in the human specimens, and the number of the nerve cells is a little larger than in the human specimens. But besides these "Terminalreticulum" and nerve cells, many thick nerve fibers are found in the cystic duct and in the neck of the gall bladder. It is almost certain that these nerve fibers, which end freely in the mucous membrane, are sensory nerves. The sensory nerve endings of the dog's gall bladder show a little more complicated shape than those of the human being, but neither a tangled ending nor a specific end-apparatus is found. Sensory nerve endings are found only in the neck of the gall bladder and in the cystic duct, and no ending is found in the body and the fundus of the gall bladder.

In the biliary tract of dogs, the myelinated nerve fibers can be traced to the extremely peripheral layer. Especially in the cystic duct and in the neck of the gall bladder, myelinated nerve fibers are often found in the mucous membrane, around the glands, or just beneath the epithelium. (Figs. 15, and 16.)

b) Common bile duct

As for the common bile duct, it was difficult to get fresh human specimens and research on the sensory nerve endings could not be complete.

Besides the autonomic "Terminalreticulum", many thick nerve fibers are found in the mucous membrane of the human common bile duct. Therefore, it can be presumed that sensory nerve endings exist also in the common bile duct. Considering the disrtibution of these thick nerve fibers and that of the myelinated nerve fibers, the sensory nerve endings in the common bile duct are probably fewer than in the cystic duct or in the neck of the gall bladder.

In the common bile duct of dogs, bundles of thick nerve fibers can be traced along its wall in the subserous or muscular tissue, and some of them run through the muscle layer to enter the mucous membrane. In the mucous membrane, sensory nerve endings are found under the epithelium or near the glandular tissue, though they are few. (Fig. 14.) Many myelinated nerve fibers are found in the common bile duct, and they can be traced to the peripheral layer. Sensory nerve endings in the common bile duct are fewer than in the cystic duct. Most of the

nerve fibers found in the common bile duct can be considered to be autonomic nerve fibers, because they connect with the nerve plexus of the biliary wall. To distinguish the sensory nerve ending strictly from these autonomic nerves, the sensory nerve ending must be sought in the very peripheral layer. Endings of the common bile duct are mostly simple, and no complicated ending is found. I found only one tangled peripheral structure of the sensory nerve in the muscle of the common bile duct of a dog, and such a complicated structure needs further investigation. (Fig. 13)

In the submucous tissue near the duodenal papilla, a few thick nerve fibers, that acquire a myelin sheath, can be recognized. They are found at a slight distance from the large nerve plexus around the duodenal papilla. But I could find no definite sensory nerve endings near the duodenal papilla.

Summary of Section III

1) Sensory nerve endings (SETO) are found in the biliary tract of human beings and dogs, most frequently in the cystic duct and in the neck of the gall bladder, and sometimes in the body and the fundus of the gall bladder.
2) Sensory nerve endings (SETO) in the biliary tract exist always in the mucous or submucous tissue, and are perhaps covered with a myelin sheath in the peripheral layer even near their terminals.
3) They are all simple endings, and neither a complicated termination nor a specific end-apparatus is found.

IV SYSTEMATIC OBSERVATIONS OF THE SENSORY INNERVATION OF THE BILIARY TRACT

a) Section of the dorsal roots of the spinal cord

According to S. W. RANSON, P. R. BILLNGSLEY, J. N. LANGLEY, O. FOERSTER and others, most of the visceral afferent nerves are myelinated nerve fibers derived from the sympathetic trunk. D. SHEEHAN has proved that the visceral afferent nerves, which reach sensory endings such as the VATER-PACINIAN corpuscle in the mesentery, have their cell bodies in the spinal ganglia of the dorsal roots of the spinal cord.

I examined the degeneration of the myelinated nerve fibers in the biliary tract after experimental posterior rhizotomy. Using dogs as experimental animals, operations were performed as follows.

Laminectomy was performed, the spinal canal was opened, the dorsal roots were carefully separated from the ventral roots, and only the dorsal roots were cut bilaterally at a point distal to their ganglia. The clinical and physiological findings show that the lower part of the thoracic cord must be anesthetized to make the biliary tract insensitive. My experimental rhizotomy was performed over the thoracic segments from Th. 5. to Th. 13.

Degenerated nerve fibers in the biliary tract could be found most frequently after the section of the dorsal roots from Th. 8. to Th. 13. So, experiments were

repeated over the thoracic segments below Th. 8. A few degenerated nerve fibers could be found 4 days after the operation. Observation 6 days after the operation was most suitable for tracing the degenerated nerve. In the specimens taken more than 6 days after operation, some of the nerves had already disappeared and their degenerating process could not be observed.

After posterior rhizotomy of the thoracic segments below Th. 8, most of the myelinated nerve fibers in the biliary tract degenerate. The myelin sheathes of these nerves are stained unequally, broken at places, and look like granules or beads. The degeneration of the myelinated nerve fibers is found frequently in nerve bundles in the subserous and muscular layers, and sometimes in the peripheral (under the mucous membrane, around the glands, etc.) layer. Under the mucous membrane of the duodenum, degenerated nerves can be found near the duodenal papilla. (Figs. 17, 19, 20, 21, and 22.)

Degenerated nerve fibers in the peripheral layer are most numerous in the cystic duct and in the neck of the gall bladder, but rather few in the common bile duct and near the duodenal papilla. As the normal myelinated nerve fibers are few in the fundus and the body of the gall bladder, their degeneration is found rarely in these parts.

It can be proved with SETO's Method that the axis cylinder is also degenerated when the myelin sheath is degenerated. The degenerated axis cylinders are broken at places, and their thickness is unequal. (Fig. 18.)

Almost all of the myelinated nerve fibers in the biliary tract, when examined in detail, show degeneration after posterior rhizotomy. But even after rhizotomy of many segments extending from Th. 6 to Th. 13., not only myelinated nerve fibers with no sign of degeneration but also apparently normal sensory nerve endings, though they are few, can be found.

b) Section of the vagus nerve

Many physiological experiments support the theory that the biliary tract is innervated by the vagus nerve. S. W. RANSON, C. D. ALPERT, J. O. FOLEY and others insist from the histological standpoint that the visceral afferent nerves are derived from the vagus nerve. Degeneration of the nerve fibers in the biliary tract after vagotomy was studied as follows.

1) Section of the vagus on the right side (in the neck distal to the ganglion nodosum)

No degeneration of either the myelin sheath or the axis cylinder can be proved in any part of the biliary tract 4 — 8 days after vagotomy. The number of the myelinated nerve fibers and the distribution of the sensory nerve endings are about the same as those of the normal biliary tract.

2) Section of the vagus nerve on the left side (in the neck distal to the ganglion nodosum)

In the cystic duct and in the neck of the gall bladder, degeneration of the myelinated nerve fibers can be found in the subserous tissue surrounding the capi-

llaries 6 days after vagotomy. (Fig. 23) This degeneration is morphologically the same as that observed after posterior rhizotomy. To prove the degeneration of the nerves in the more peripheral layer, specimens were observed 4 — 14 days after vagotomy. But this is very rare and it is only in the subserous tissue that degenerated nerves are found in the cystic duct and in the neck of the gall bladder after left vagotomy. In cases, in which degenerated nerve fibers are found in the subserous tissue, myelinated nerve fibers in the peripheral layer are apparently normal and sensory nerve endings can be recognized definitely. 6 — 7 days after vagotomy, degeneration of the myelinated nerve fibers can be found in the myenteric plexus near the duodenal papilla.

3) Section of the vagus nerve on both sides

Bilateral vagotomy can not be performed in the neck at one time without killing the dog. So, the vagus nerves of both sides were cut with the interval of 2 — 3 days. However, after this bilateral vagotomy, no degenerated nerves could be found in any part of the biliary tract. Therefore, both the ventral and dorsal branches of the vagus nerves were cut in the thorax distal to the anastomosis of the vagus nerves.

A few degenerated nerve fibers can be observed only in the subserous tissue of the cystic duct 6 — 7 days after vagotomy. No change can be proved in the myelinated nerve fibers in the peripheral layer and in the sensory nerve endings, though the myelinated nerve fibers in the myenteric plexus of the duodenum sometimes show degeneration.

Summarizing the results after unilateral and bilateral vagotomies, secondary degenertion of the nerves can be found always in the subserous tissue or in the myenteric plexus, and no degenerated nerves can be demonstrated in the more peripheral (under or in the mucous membrane) layer. In other words, no degenerated nerves can be found in the peripheral layer beyond the nerve plexus of the biliary wall.

c) Phrenicotomy

According to clinical findings, biliary pain radiates to the right shoulder. This fact is usually explained by the conduction of biliary sensitivity to the right phrenic nerve. But this explanation has not been proved histologically.

Using dogs as experimental animals, the phrenic nerve was drawn out in the neck as long as possible. A few days after the operation, degenerated nerves were examined after having ascertained by thoracotomy that the phrenic nerve had been surely removed. Phrenicotomy was performed mostly on the right side, but also the left phrenic nerve was cut as a control.

4 — 10 days after the operation no degenerated nerves can be found in any layer of the biliary tract or the duodenum. The number of myelinated nerves and the distribution of the sensory nerve endings there are not changed after phrenicotomy.

However, I did find one single specimen which showed degeneration of the

myelinated nerve fibers in the connective tissue around the common bile duct after right phrenicotomy. (Fig. 24.)

V DISCUSSION

I looked for sensory nerve endings in the biliary tract on the basis of STOEHR and SETO's theory of the autonomic "Terminalreticulum". The thick nerves which teminate freely in the periphery without forming the "Terminalreticulum" were marked as sensory nerves in this study. However, it is certain that besides the "Terminalreticulum" autonomic nerve fibers also exist in the biliary tract. The sensory nerves must be strictly differentiated from these autonomic nerves. The stumps of the autonomic nerve fibers in the subserous tissue look just like sensory nerve endings. In this case, it is very difficult to differentiate the sensory nerve morphologically from the autonomic nerve fibers. The thick nerves, existing in the subserous layer and resembling the sensory nerve endings, are excluded in this study. In the periphery beyond the nerve plexus of the biliary wall, the autonomic nerves form the "Terminalreticulum". Therefore, the thick nerves, which terminate freely in the periphery with no connection to nerve cells, cannot be considered autonomic nerves. Sensory nerve endings sometimes approach glandular tissue, but their number is very small compared to the number of glands. The distribution of sensory nerve endings is not always equal to the number of glands. The sensory nerves near the glands are, if examined in detail, traced only around or beneath the glands, but they never enter the glands themselves. So, it is inconceivable that these nerves innervate the glands directly. The myelinated nerves of the biliary tract can be traced to the very peripheral layer, and their course and distribution are quite equal to those of the sensory nerves. Judging from these findings, the sensory nerves are myelinated in their periphery even near their terminals. According to the results of my experiments, most of these myelinated nerves are derived from the dorsal roots of the spinal cord, and they do not interchange their neurons to the periphery. It is almost certain that these myelinated nerves are sensory nerves.

According to M. CLARA, the morphological characteristics of sensory nerve endings are the specific structures which extend the surface at their teminal. G. WEDDELL insists, on the basis of his study of sensory nerve endings in the skin, that the structure of the sensory terminals is usually free-ending arborization, and that some of the complicated terminations may be sometimes considered to be an artefact in the staining process. The results of my study are in agreement with his opinion. In inadequately-stained preparations or those made from small flexible pieces of tissue like the dog's common bile duct, the stumps of the nerve fibers often resemble tangled endings. In view of these facts, it is necessary to consider the artificial changes produced by the staining process in discussing the structure of the sensory nerve ending.

According to H. MIYAKE and others, the extrinsic nerves of the biliary tract

are derived from the celiac ganglia of both sides and are traced downwards from the neck of the gall bladder along the common bile duct. The distribution of the sensory nerve ending is in agreement with the results of H. MIYAKE's study. It is quite natural that the sensory nerve ending is most frequently found in the cystic duct and in the neck of the gall bladder, for these parts are innervated bilaterally by the celiac ganglia. Considering the distribution of the sensory nerve ending, it can be stated that the cystic duct and the neck of the gall bladder play an important role in causing biliary pain.

Degenerated nerve fibers can be found in the subserous tissue after vagotomy, though it is possible that these nerves relay their impulses through neurons in the nerve plexus of the biliary wall. It is doubtful that these degenerated nerves can prove the existence of sensitivity derived from the vagus nerve. But, in future, secondary degeneration of nerve fibers in the peripheral layer beyond the nerve plexus of the vagotomized biliary tract may be proved by another method. Considering the physiological function of the vagus nerve on the biliary system, and in view of the experimental results showing that sensory nerve endings can be found after posterior rhizotomy of many segments, the existence of afferent innervation derived from the vagus nerve can not be denied.

The results of my experiments show that most of the sensory nerves of the biliary tract are derived from the spinal cord (i. e. sympathetic nerves), and that the afferent nerves derived from the vagus nerve are very few, if they exist at all. These findings are of interest with reference to the clinical finding that biliary pain is not always accompanied with vomiting.

The relation between the phrenic nerve and the sensitivity of the biliary tract can not be proved. In only one case, degenerated nerve fibers were found around the biliary tract after right phrenicotomy. But it is doubtful whether the nerves, derived from the phrenic nerve and reaching the biliary tract, are always sensory nerves. It can be presumed, however, that the radiation of biliary pain to the right shoulder is not due to the sensation of the biliary tract itself, but to the inflammatory stimuli extending over the surrounding tissues.

H. SETO insists that the autonomic "Terminalreticulum" never degenerates after section of the autonomic nerve trunk. In my experiments, no change is recognizable in the autonomic "Terminalreticulum" after all kinds of operative procedure on the dorsal roots of the spinal cord and on the vagus nerve.

A part of this study has been already reported by Ch. KIMURA in "Systematic Histological Study of Sensory Nerve Endings in the Alimentary Canal". P. STOEHR Jr., who kindly introduced our works in his "Zusammenfassende Ergebnisse über Endigungsweise des vegetativen Nervensystems", described that Ch. KIMURA marked in his report the "Schlängende Territorien (STOEHR)" as the sensory nerve ending. But our sensory nerve ending is quite different from the so-called "Schlängende Territorien (STOEHR) (Winding territories)", because it is always a nerve fiber itself or a fiber bundle neither having an appearance of

"Leitplasmodium (Leading plasmodium)" nor the terminal meshwork in it.

The "Periterminalreticulum" supported by J. Boeke, J. JABONERO and others were not examined in this study. T. KURE insits on the existence of the spinal parasympathetic system, but it is not completely proved from the histological point of view.

In this study, sensory nerves with myelin sheathes are studied : but I never deny the existence of a sensory nerve system consisting of non-myelinated nerve fibers. I have studied sensory nerves on the basis of P. STOEHR and H. SETO's theory and ascertained that they could be sensory nerves also from the standpoint of J.N. LANGLEY's neuron theory. I am sure that the sensory nerves described above are definite enough to prove the sensitivity of the biliary tract.

VI SUMMARY AND CONCLUSION

1) Simple sensory nerve endings (SETO) are found under or in the mucous membrane of the gall bladder, cystic duct. and common bile duct of human beings and dogs.
2) Neither sensory nerve endings with a complicated structure nor specific end-apparati are found in the biliary tract.
3) The sensory nerve endings of the biliary tract are perhaps covered with a myelin sheath even in the peripheral layer, and they are most frequently found in the cystic duct and in the neck of the gall bladder.
4) In the fundus and body of the gall bladder, sensory nerve endings are very few.
5) Sympathetic afferent nerves of the biliary tract are derived from dorsal roots of the spinal cord.
6) As for the afferent innervation of the biliary tract, sympathetic innervation is more domiant than that of the vagus nerve.
7) The relation between biliary sensitivity and the phrenic nerve can not be proved directly.
8) The sensory nerve ending in the biliary tract is quite different from the so-called "Schlängende Territorien (STOEHR) (Winding territories)".

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EXPLANATION OF FIGURES

1) Ph.···Photomicrographs from the preparations.
   Dr.···Drawings from the preparations.
2) Roman figures show the number of magnifications.
3) S,···Sero's staining method.
   E.···Ehrlich's staining method.
4) Letters in the figures indicate,
   Ep.···Epithelium of the mucous membrane,
   SM.···Smooth musculature,
   TR.···Autonomic "Terminalreticulum",
   Gl.···Glands.

和文抄録

胆道の知覚神經の組織学的研究

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BIELSCHOWSKY 氏神経鍍銀法の瀬戸氏変法及び EHRLICH 氏神経髄鞘染色法を用い，新鮮なる胆道標本（人及び犬）に於て知覚神経終末の形態及び分布を検索し，更に脊髄後根（Th.5 — Th.13），迷走神経，及び横隔膜神経を実験的に切断せる犬の胆道組織内の末梢神経の二次変性を追求し，之等の結果より胆道知覚に関し次の如き結論を得た。

1) 人及び犬の胆嚢，胆嚢管及び輸胆管の粘膜下には単純な形状の知覚神経終末（瀬戸）が発見される．

2) 胆道組織内には複雑な構造を有する知覚神経終末も，特殊終末装置も発見されない．

3) 胆道の知覚神経終末は可成末梢まで有髄と思われる．

4) 胆道の知覚神経終末は胆嚢頸部及び胆嚢管に最も多く，胆嚢の底部及び体部には甚だ少数で有る．

5) 胆道を支配する交感神経性求心神経は明かに脊髄後根を通る．

6) 胆道の知覚支配に関しては，脊髄性交感神経性支配が迷走神経性支配に比して遙かに優性である．

7) 横隔膜神経と胆道知覚との間には直接の関連は立証出来ない．

8) 上記の知覚神経は Ph. STOEHR, Jr. の云う “Schlängende Territorien（蛇行領域）” とは全く別個の神経線維で有る．

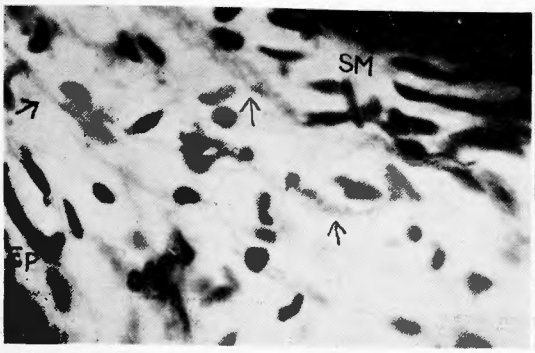

Fig. 1. "Praeterminal- and Terminalreticulum" in the mucous membrane of a human gall bladder. Ph. ×400×1.5. S.

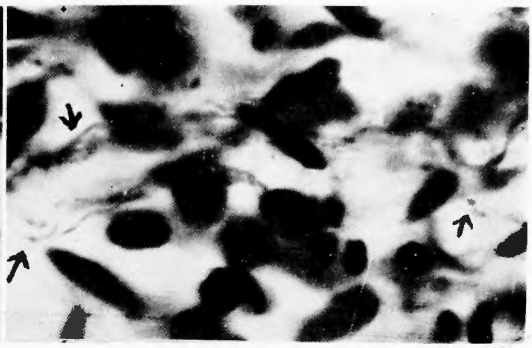

Fig. 2. "Praeterminal- and Terminalreticulum" in the mucous membrane of a human cystic duct. Ph. ×1000. S.

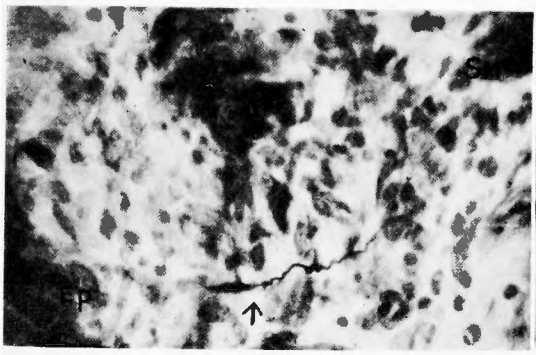

Fig. 3. A sensory nerve ending in the submucous tissue of a human gall bladder. Ph. ×320×2. S.

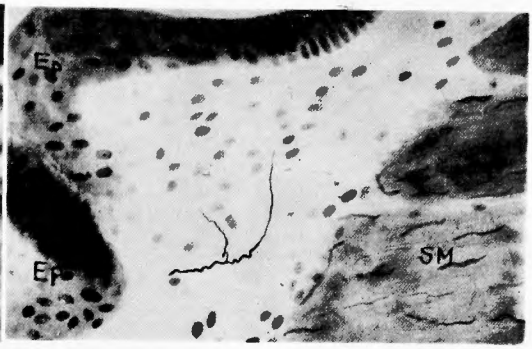

Fig. 4. A sensory nerve ending in the mucous membrane of a human gall bladder. Ph. ×320×2. S.

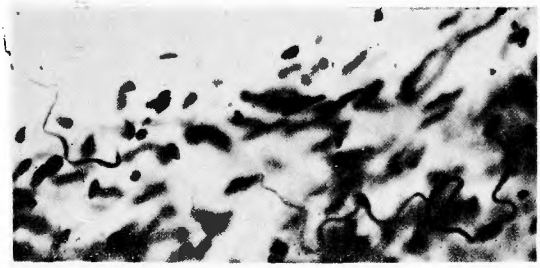

Fig. 5. A sensory nerve ending in the mucous membrane of a human gall bladder. Ph. ×320×2. S.

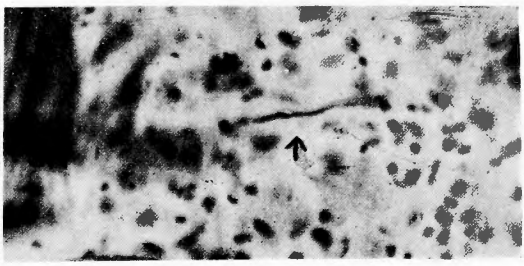

Fig. 6. The same preparation as Fig. 5. Dr. ×320×1.5 S.

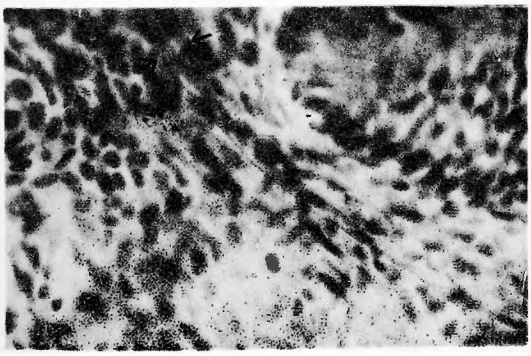

Fig. 7. A sensory nerve ending in the mucous membrane of a human gall bladder. Ph. ×320×2. S.

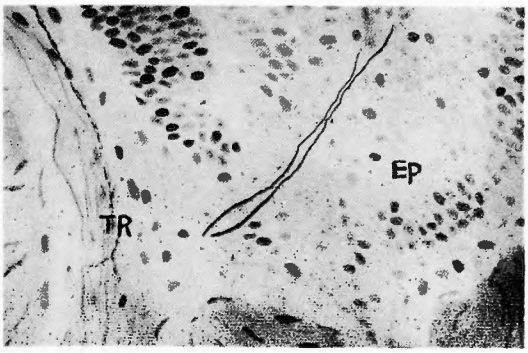

Fig. 8. The same preparation as Fig. 7. Dr. ×600×3/4. S.

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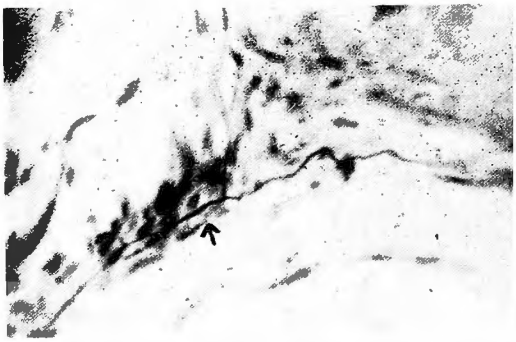

Fig. 9. A sensory nerve ending in the mucous membrane of a human cystic duct. Ph. ×320×2. S.

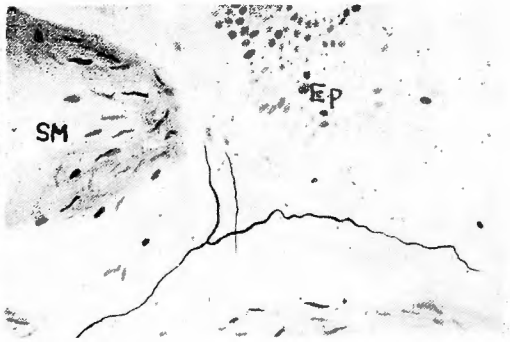

Fig. 10. The same preparation as Fig. 9. Dr. ×320. S.

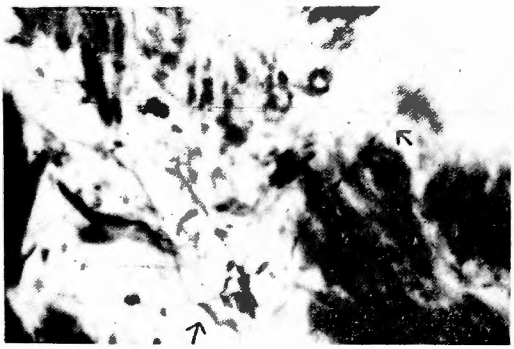

Fig. 11. A sensory nerve ending in the mucous membrane of a human cystic duct. Ph. ×320×2. S.

Fig. 12. The same preparation as Fig. 11. Dr. ×320×1.5. S.

Fig. 13. A tangled sensory nerve ending? between the muscle of the common bile duct of a dog. Ph. ×320×2. S.

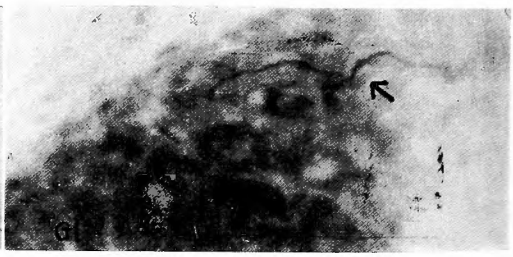

Fig 14. A sensory nerve ending that approaches the gland in the common bile duct of a dog. Ph. ×640×1.2. E.

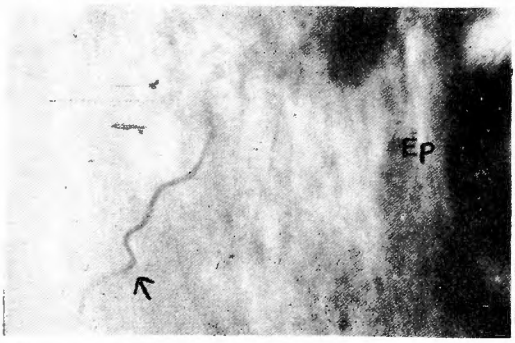

Fig. 15. A myelinated nerve fiber in the mucous membrane of the gall bladder of a dog. Ph. ×640. E.

Fig. 16. A myelinated nerve fiber in the mucous membrane of the cystic duct of a dog. Ph. ×640. E.