# THE TRANSPLANTATION OF AUERBACH' S PLEXUS IN THE SMALL INTESTINE OF A DOG TO THE BLADDER WALL AND OVARY, AND A NEURO-HISTOLOGICAL STUDY ON THE ATTITUDE OF THE TRANSPLANTED GANGLION CELLS IN THE PLEXUS

by

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**Contents**



## I INTRODUCTION

The digestive tract is influenced by the autonomic nerve, namely, on principle it is promoted by the excitement of the parasympathetic nerve and inhibited by the sympathetic nerve. The intestine performing the peristaltic motion by mechanic stimulations without the extrinsic nerves is due to the action of intramural plexuses.

Since AUERBACH (1862) described the network structures of the nervous tissue in the muscle layer of the intestine, GREVING, DOGIEL, KUNTZ and others have investigated this plexus histologically and also, MAGNUS, ESVELD, YANASE and others have observed the peristaltic motion controled by AUERBACH's plexus physiologically. But among the many reports on the anatomy, physiology and histology of AUERBACH's plexus, the author have never seen a single report describing its transplantation.

Accordingly, the author carried out the transplantation experiments of AUERBACH's plexus in the small intestine to the bladder wall and ovary, and the attitude of the transplanted ganglion cells in the plexus were studied histologically.

## II MATERIALS AND METHODS

Operations were performed as follows ; Laparotomy was carried out under general anesthesia with the injection of isomytal sodium. The sparrow egg-sized serous membrane of the small intestine was peeled in the portion 1 meter oral from the ileum end so that the surface of muscle layer was exposed, and the naked muscle layer was sutured to the base of the bladder, 2–4 weeks after the operation, laparotomy was again performed. As stiff adhesion was found between the bladder and the intestine, it was peeled from the intestine side so as to leave the muscle layers of the intestine on the base of the bladder. The part of the intestine, from which the muscle layers were removed, was resected and a side to side anastomosis was carried out.

Thus the transplantation of AUERBACH's plexus of the intestine together with the muscle piece was completely performed, because it was perfectly isolated from the mesenteric blood vessels and nerves.

The muscle piece of the intestine was removed together with the adhered bladder wall as a mass 1, 3 and 6 months after the transplantation respectively and was used as a specimen.

The ovary specimens were obtained by the same method.

All the materials used in this study were obtained from adult dogs. The author used only fresh specimens which were resected operatively. After fixation for 3–4 weeks in 10% neutral formal solution, the specimens were frozen, sliced in thickness of 30–40$\mu$, fixed again 10% neutral formal solution for more than 2–4 months, and then stained. The author recognized AUERBACH's plexus which was stained with Suzuki's modification of BIELSCHOWSKY's silver impregnating method.

## III MICROSCOPIC OBSERVATION OF THE TRANSPLANTED AUERBACH'S PLEXUS OF THE SMALL INTESTINE ON THE URINARY BLADDER AND OVARY

AUERBACH's plexus is a nerve tissue in the connective tissue space between the ring and longitudinal muscles of the intestine wall, and it consists of nerve cells and nerve fibers. The srtucture of AUERBACH's plexus is divided into 3 portions, i. e. the primary, the secondary, the tertiary plexus. The primary plexus consists of many ganglion cells and nerve fibers, and is localised between the circular and longitudinal muscle layers. The secondary plexus consists of a few ganglion cells and fine nerve fibers. It arises from the primary plexus, enters the muscle layers, and is localised in the connective tissue between muscle fibers. The tertiary plexus ramifies from the secondary plexus, consists of fine nerve networks, and distributes to each muscle fiber.

Nerve cells usually exist in the primary plexus, and they have been differentiated into two types by DOGIEL (1895). Type I nerve cell has many short axons and a few long axons, the formers terminate in the nerve cell capsule without passing through it, while the latters form the neurites, traversing the

capsule. Type I nerve cell mainly has plural axons, sometimes as many as 4–5 axons. Type II nerve cell has both long and short axons, however both of them run out of the capsule. Short axons in type II nerve cell are far less in number than in type I. Most of them ramify and terminate in tapering endings. The greater part of the long axons in type II show a plurality such as in type I nerve cell.

As a control of experiments, the author made an adhesion between the small intestine and the bladder wall, without cutting off the mesenteric blood and nerve supply, and adhered part of the intestine was studied.

In the control specimens, almost normal nerve structures of AUERBACH's plexus as mentioned above were observed (Fig. 1—6).

Next, observing the specimens in which the transplantation was carried out, the following findings were obtained :

(A) The AUERBACH's plexus transplanted on the bladder wall

1) At the end of the 1st month

In AUERBACH's plexus, various degrees of degenerations were found in nerve cells ; dysharmony of axons, dislocation of nucleus, and fenstrated cell, etc., were observed. In some specimen the number of nerve fibers in AUERBACH's plexus decreased, in another they proliferated, while in some others decrease and increase in the number of of nerve fibers were found in different portions of AUERBACH's plexus (Fig. 7—22).

2) At the end of the 3rd month

Mild degenerated nerve cells were found. A few specimens showed decreased number of nerve fibers, but most of specimens showed marked increase of nerve fibers with a vigorous growth toward the scar (Fig. 23—36).

3) At the end of the 6th month

It was hard to discriminate the transplanted muscle piece in the scar, AUERBACH's plexus remained as a carcase, and nerve cells or fibers were scarcely found there (Fig. 37, 38, 39).

(B) The AUERBACH's plexus transplanted on the ovary

1) At the end of 1st month

Severe degenerated nerve cells were observed, and nerve fibers were generally found to have decreased considerably without a tendency to increase (Fig. 40, 41, 42).

2) At the end of the 3rd month

Most of degenerated nerve cells commonly showed up, light stainning, falling of the argent affinity, indistinct figures and invisible axons. Nerve fibers were found to have almost disappeared (Fig. 43—48).

## IV DISCUSSION

Considering the results of various experiments performed by many investigators from the anatomical or physiological standpoint, the urinary bladder is mainly innervated by pelvic nerves and by hypogastric nerves. The pelvic nerves

belong to the sacral parasympathetic system, and the hypogastric nerves belong to the sympathetic system, while the formers are more dominant in the bladder than the latters, and the pelvic nerves play a leading innervation in the bladder. The ovary is under the innervation of the ovarian plexus, and especially is innervated by sympathetic nerves which are derived from the spinal segments of Th. 10—L. 2 like the kidney and the testis, while the parasympathetic innervation is very poor.

From these facts and neurohumoralism (DALE), it can be assumed that autonomic nerves of the bladder muscles belong to the parasympathetic system, i. e. the cholinergic nerve system, like AUERBACH'S plexus. Both are homotype. The autonomic nerves of the ovary belong to the sympathetic system, i. e. the adrenergic nerve system, therefore, AUERBACH'S plexus and the ovary are heterotype.

Next, one may think that intramural nerve cells in the digestive tract wall, i. e. cells of AUERBACH'S and MEISSNER'S plexus, are the starting point of parasympathetic-postganglionic fibers.

Then in the experiments, at the end of the 1st month after the transplantation of AUERBACH'S plexus to the bladder, the author recognized a remarkable cell infiltration, various degenerated nerve cells and fibers. It was thought that these degenerations were affected not only by cutting off the blood supply but also by the inflammation, as was expected. In the preparations of the 3rd month after the transplantation, mild degenerated nerve cells and remarkable proliferation of nerve fibers were found. Though the transplantation seemed to be possible from these results, in the preparations of the 6th month, AUERBACH'S plexus remained as a carcase, and the nerve cells and fibers had completely disappeared.

Next, in the 1st month after transplantation to the ovary, nerve cells already showed severe degenerations and nerve fibers showed a one sided remarkable decreasing without a tendency to increase. In the 3rd month, nerve cells showed a high degree of degeneration and nerve fibers almost disappeared.

From these results which the author observed, the transplantation of AUERBACH'S plexus may be impossible and once degenerated, nerve cells are irreversible.

In regard to the postganglionic fibers, they began to decrease in the 1st month. In the bladder wall which belongs to the cholinergic nerve system, they lived for a long time. They showed once proliferation, and finally in 6 months completely disappeared. In the ovary which belongs to the adrenergic nerve system, they decreased from the beginning without showing any increase, and in 3 months they disappeared.

The postganglionic nerve fibers, which were isolated from the preganglionic fibers and transplanted to other organs, show a different attitude in those organs. In a homotype organ, from the view point of chemical mediator of the innervating nerves, the nerve fibers in the transplanted muscle can be alive for a long time, i. e. for over 3 months, once showing proliferation during this time period. In a

heterotype organ, the nerve fibers in the transplanted muscle decrease the number from the beginning and completely degenerate in 3 months.

## V SUMMARY AND CONCLUSION

The author carried out the transplantation experiments of AUERBACH's plexus in the small intestine to the bladder wall and ovary, and observed the attitude of the transplanted ganglion cells in the plexus by neurohistological study. And then he investigated the change of postganglionic fibers which were isolated from the preganglionic fibers.

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

1) The transplantation of AUERBACH's plexus to the urinary bladder and ovary may be impossible. If it is possible, it will be in the bladder.

2) The postganglionic fibers of the parasympathetic nerve begin to decrease in about one month after the isolation, and then go through different courses by the type of nerve innervation;

(a) In the homotype organ (the bladder) which belongs to the cholinergic nerve system, they live a relatively long time.

(b) In the heterotype organ (the ovary) which belongs to the adrenergic nerve system, they continue to decrease to earlier death.

I wish to express my deepest gratitude toward Assist. Prof. Dr. Ch. KIMURA for his helpful advice and kind guidance throughout this study.

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## Suzuki's Method

The specimens, after having been sliced with the freezing method and kept in 10% neutral formal solution, are

1) Washed 3 times with distilled water, each time for about 10 minutes,
2) Put into 20% silver nitrate solution for about 1 hour, in the darkness,
3) Washed with distilled water for a few seconds,
4) Put into ammonical silver solution until the specimens are colored light yellow,
5) Placed in 10% sodium-potassium tartrate solution for a few minutes until the specimens are colored gold yellow,
6) Washed with distilled water for a few minutes,
7) Placed in 0.05-0.1% gold choride solution for 1-2 hours,
8) Washed with distilled water for a few minutes,
9) Placed in 20% sodium thiosulfate solution,
10) Washed in distilled water,
11) Dehydrated and mounted.

和文抄録

# アウエルバッハ氏神経叢の膀胱及び卵巣への移植並びに移植神経叢の消長に関する組織学的研究

京都大学医学部外科学教室第2講座（指導：青柳安誠教授）

野村源藏

成犬小腸のアウエルバッハ氏神経叢を膀胱及び卵巣へ移植し，移植後1カ月，3カ月，6カ月の標本に於て，移植神経叢の消長並びに節前線維より遮断された副交感神経節後線維に就て検討し，次のような結論を得た．

1）移植後1カ月，膀胱に於ては著明な細胞浸潤を認め，アウエルバッハ氏神経叢の神経細胞には核偏位，有窓細胞等種々の変性が強く，神経線維は或標本に於て減少し，又他の標本に於ては増殖しているのが認められた．更に神経線維の増殖減少が同一標本に於て異なつた場所に認められることもあつた．これらの変化は血流遮断によるだけではなく，炎症の影響を強く受けていると考えられ，

2）3カ月の標本に於て，神経細胞の変性は少なく，神経線維は極く少数の標本に於て減少しているが，多くの標本に於ては著しく増殖し瘢痕へ伸びて行くのが認められた．この結果から移植可能と思われたが，

3）6カ月の標本に於て，移植筋肉片は瘢痕と判別し難く，アウエルバッハ氏神経叢は残骸を残す状態で，神経細胞及び神経線維は全く消失していた．

4）次に卵巣への移植は移植後1カ月に於て，既に神経細胞には高度の変性が認められ，神経線維は全く増殖の傾向なく一方的に著しく減少しているのが認められた．

5）3カ月の標本に於ては，神経細胞の変性が更に高度となり，神経線維は全く消失していた．

6）以上の結果から，アウエルバッハ氏神経叢の移植は不可能である．若し可能であるとすれば，それは膀胱に於てであろう．

7）節前線維より遮断され，他の臓器に移植された節後線維は約1カ月内に減少し始め，その後神経支配の型によつて態度を異にする．

(a) 同型の臓器，即ち向コーリン神経系に属する膀胱に於ては，副交感神経節後線維は比較的長く3カ月以上も生存し，

(b) 異型の臓器，即ち向アドレナリン神経系に属する卵巣に於ては，副交感神経節後線維は減少の一途を辿り早期に消失する．

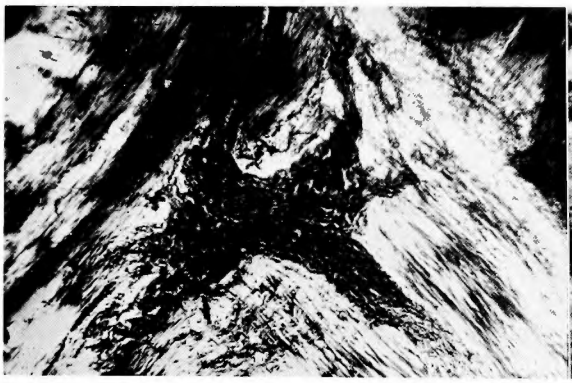

**Fig. 1** The control specimen. The primary and secondary plexuses in the AUERBACH's plexus of the small intestine. ×100

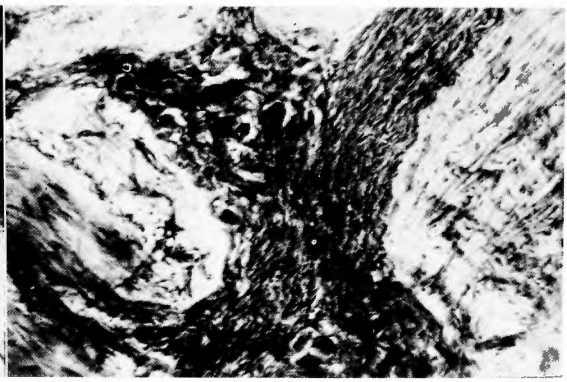

**Fig. 2** Enlargement of Fig. 1. The primary plexus. × 200

**Fig. 3** Enlargement of Fig. 1. Abundant nerve cells and fibers in the primary plexus. ×400

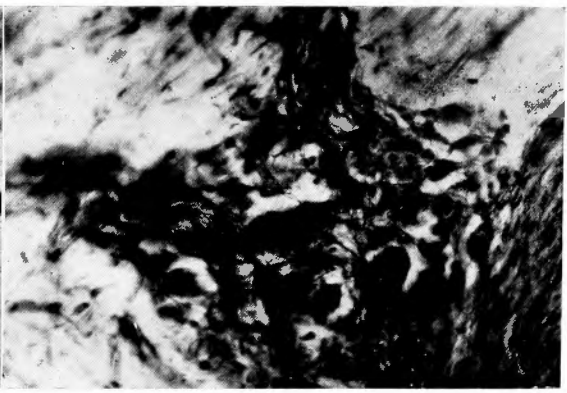

**Fig. 4** Enlargement of Fig. 1. The same state as in Fig. 3. ×400

**Fig. 5** The control specimen. The primary and secondary plexuses. ×100

**Fig. 6** Enlargement of Fig. 5. Abundant nerve fibers in the AUERBACH's plexus. ×400

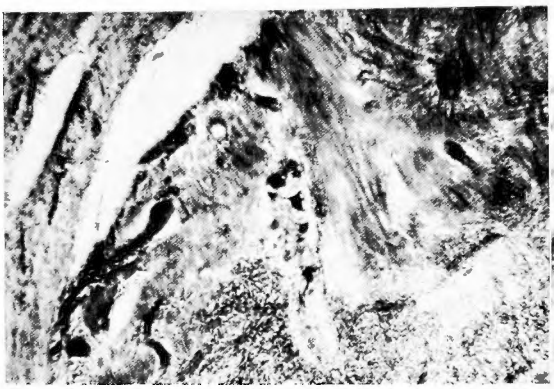

**Fig. 7** A notable cell infiltration 1 month after the transplantation of AUERBACH's plexus to the bladder wall. ×100

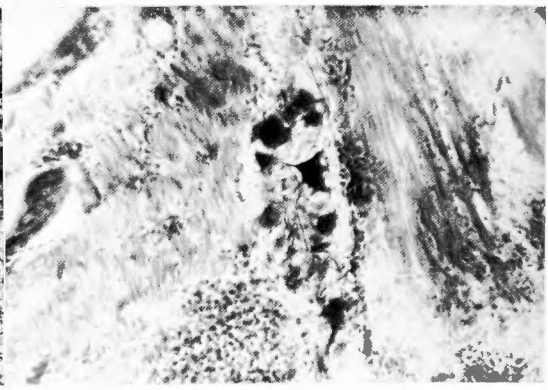

**Fig. 8** Enlargement of Fig. 7. ×200

**Fig. 9** Enlargement of Fig. 7. Decreased nerve fibers in the AUERBACH's plexus. ×400

**Fig. 10** Degenerative changes in the AUERBACH's plexus 1 momth after the transplantation to the bladder wall. ×200

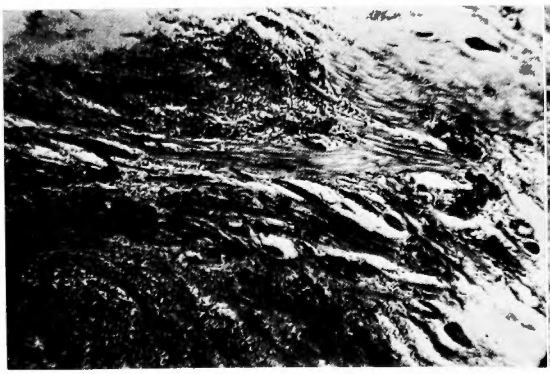

**Fig. 11** A notable cell infiltration 1 month after the transplantation of AUERBACH's plexus to the bladder wall. ×100

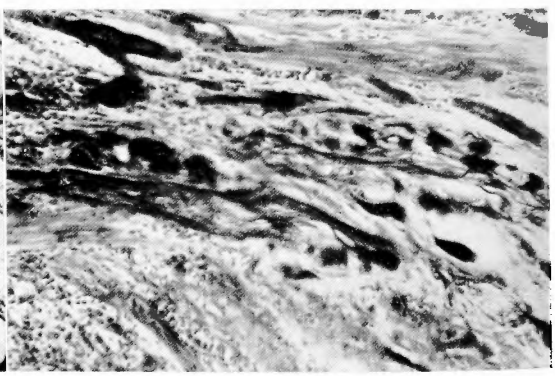

**Fig. 12** Enlargement of Fig. 11. Partial proliferation of nerve fibers. ×200

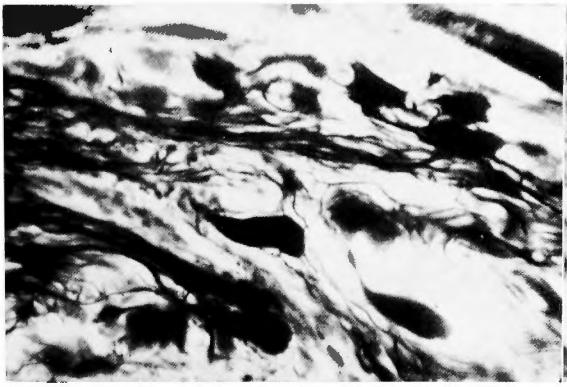

**Fig. 13** Enlargement of Fig. 11. Shrinkage and the hyperchromasia of cytoplasma of nerve cells. ×400

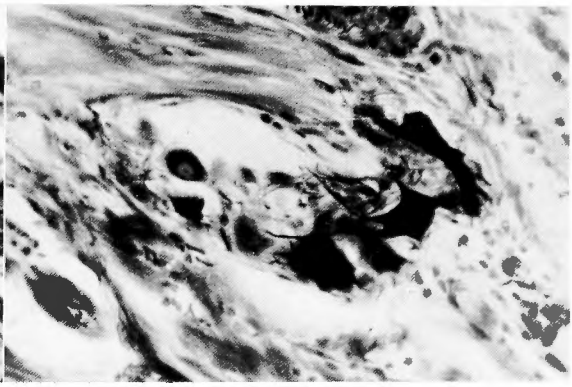

**Fig. 14** Dysharmonious axons and decreased nerve fibers of degenerated-nerve cells, 1 month after the transplantation to the bladder wall. ×400

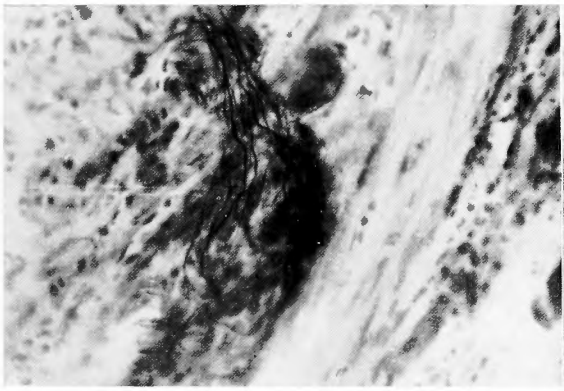

**Fig. 15** Decreased nerve fibers 1 month after the transplantation to the bladder wall. ×400

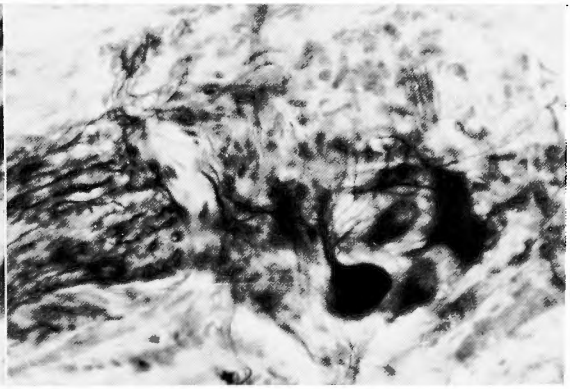

**Fig. 16** Decrease of nerve cells and nerve fibers, 1 month after the transplantation to the bladder wall. ×400

**Fig. 17** Slight increase of nerve fibers 1 month after the transplantation to the bladder wall. ×400

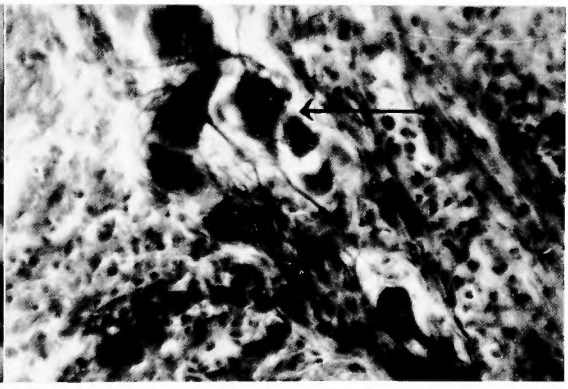

**Fig. 18** A fenstrated cell in AUERBACH's plexus 1 month after the transplantation to the bladder wall. ×400

**Fig. 19** Dislocation of nucleus in type I nerve cell (DOGIEL) 1 month after the transplantation to the bladder wall. ×900

**Fig. 20** Decrease of the satellite cells of ganglionic cells (DOGIEL type I neuron)and dislocation of nucleus 1 month after the transplantation to the bladder wall. ×900

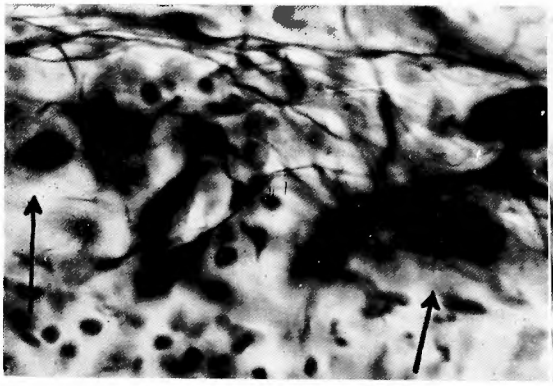

**Fig. 21** Normal type Ⅱ nerve cells (DOGIEL) and shrinkage of cytoplasma in type I nerve cells, 1 momth after the transplantation to the bladder wall. ×900

**Fig. 22** A type Ⅱ nerve cell (DOGIEL) s remained without a marked change, 1 month after the transplantation to the bladder wall. ×900

**Fig. 23** Mild cell infiltration 3 months after the transplantation to the bladder wall. ×100

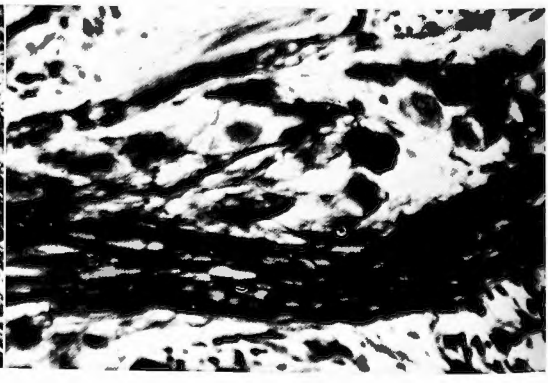

**Fig. 24** Enlargement of Fig. 23. Proliferation of nerve fibers. ×400

**Fig. 25** Enlargement of Fig. 23. Strongly increased nerve fibers. ×400

**Fig. 26** Nerve cells remaining intact without marked changes, and slight decrease of nerve fibers 3 months after the transplantation to the bladder wall. ×400

**Fig. 27** Slight decrease of nerve fibers with mild cell infiltration 3 months after the transplantation to the bladder wall. ×100

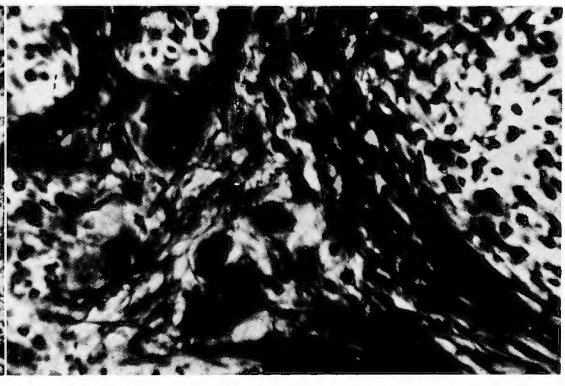

**Fig. 28** Enlargement of Fig. 27. Almost normal AUERBACH's plexus (The primary plexus). ×400

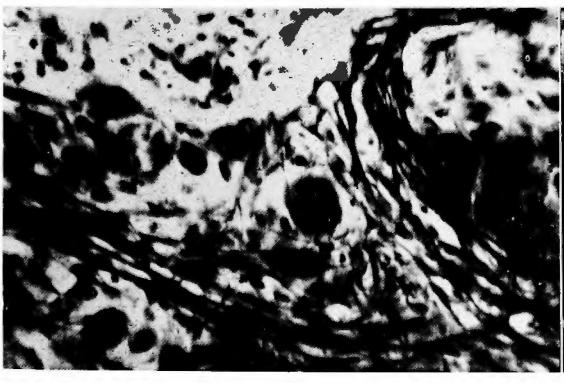

**Fig. 29** Enlargement of Fig. 27. Nerve fibers increase in one portion and decrease in another. ×400

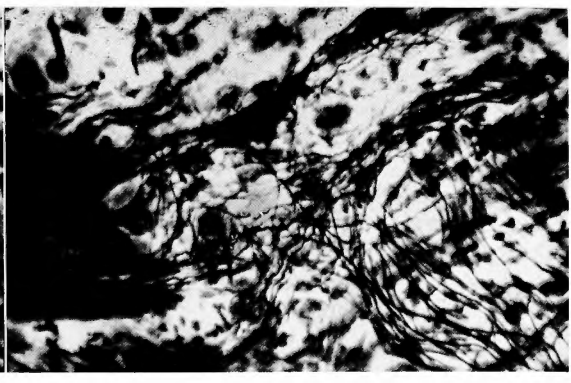

**Fig. 30** Enlargement of Fig. 27. Partial disappearance of nerve cells remaining spaces in the AUERBACH's plexus. ×400

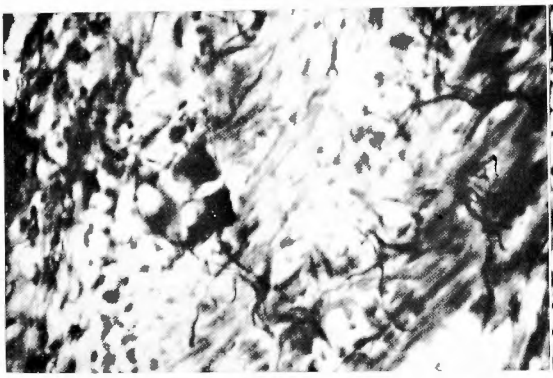

**Fig. 31** A notable decrease of nerve cells and fibers 3 months after the transplantation to the bladder wall. ×400

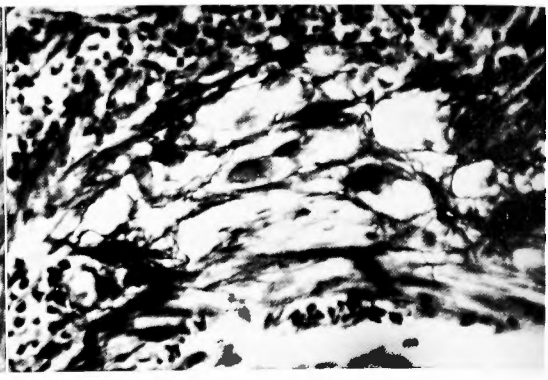

**Fig. 32** Shrinkage and transparency of cytoplasma in the the primary plexus 3 months after the transplantation to the bladder wall. ×400

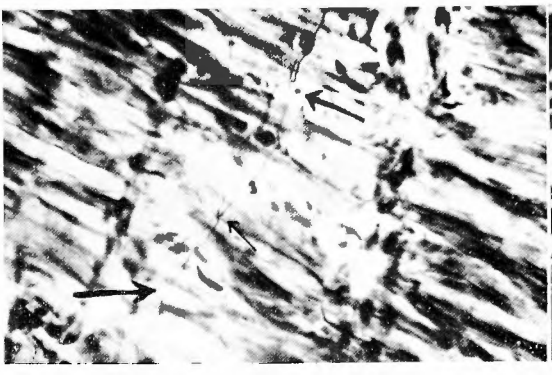

**Fig. 33** A fine nerve fiber running toward the muscle fiber (the tertiary plexus) 3 months after the transplantation to the bladder wall. ×400

**Fig. 34** Nerve cells are stained heavily and one of them has a vacuole, 3 months after the transplantation to the bladder wall. ×900

**Fig. 35** Shrinkage of cytoplasma and decrease of nerve fibers 3 months after the transplantation to the bladder wall. ×900

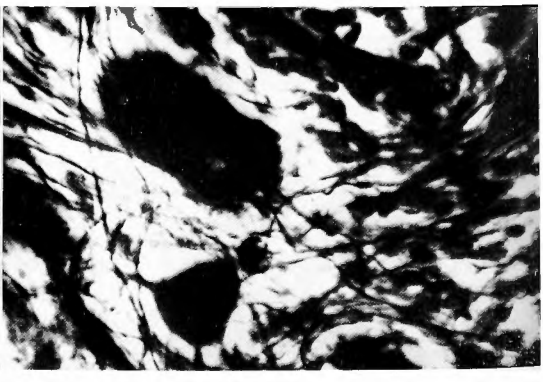

**Fig. 36** Nerve cells are stained heavily and partial increase of nerve fibers is shown, 3 months after the transplantation to the bladder wall. ×900

**Fig. 37** A carcase of AUERBACH's plexus in the scar, 6 months after the transplantation to the bladder wall. ×30

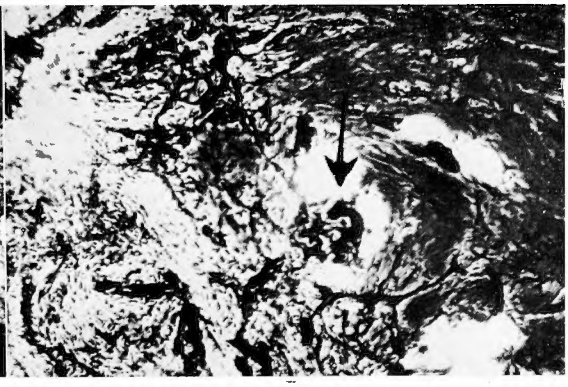

**Fig. 38** Enlargement of Fig. 37. ×200

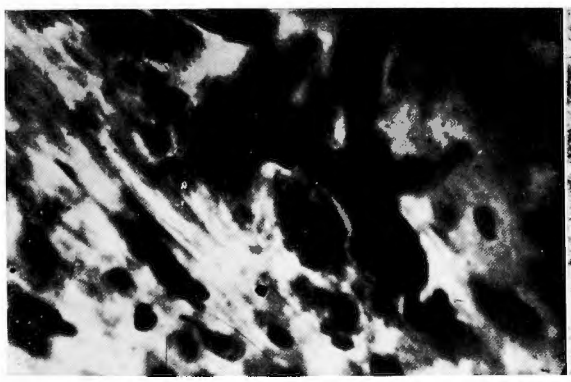

**Fig. 39** Enlargement of Fig. 37. Destroyed nerve cells and disappearance of nerve fibers. × 900

**Fig. 40** Atrophied AUERBACH's plexus 1 month after the transplantation to the ovary. ×100

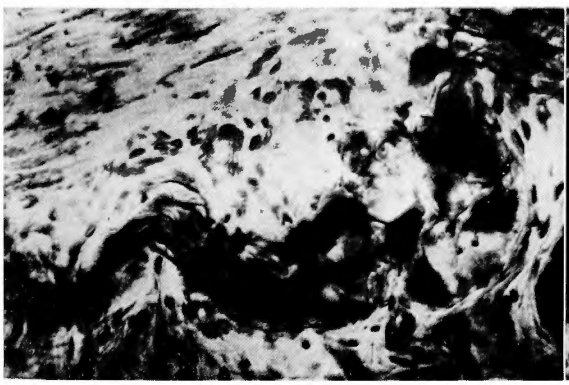

**Fig. 41** Enlargement of Fig. 40. A considerable decrease of nerve fibers. ×400

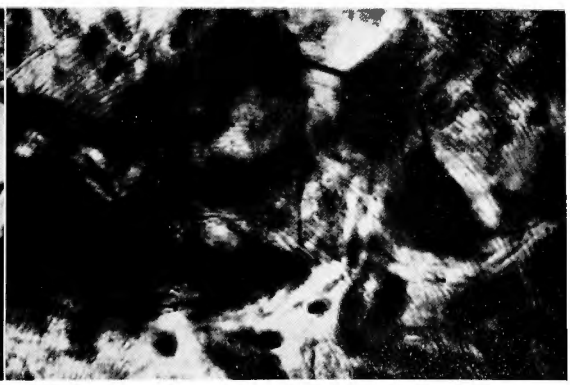

**Fig. 42** Enlargement of Fig. 40. The indistinct figure of nerve cells due to degenerations and broken nuclei. ×900

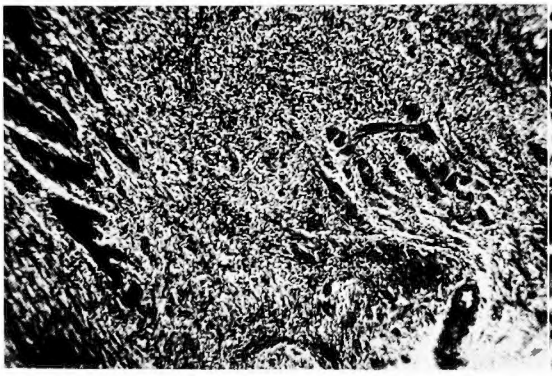

**Fig. 43** A notable cell infiltration 3 months after the transplantation to the ovary. ×100

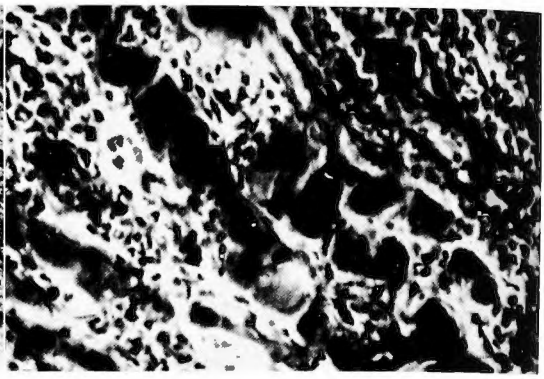

**Fig. 44** Enlargement of Fig. 43. Disappearance of axons and nerve fibers. ×400

**Fig. 45** Enlargement of Fig. 43. Breaking of nucleus in nerve cells. ×900

**Fig. 46** Atrophied AUEKBACH's plexus 3 months after the transplantation to the ovary. ×100

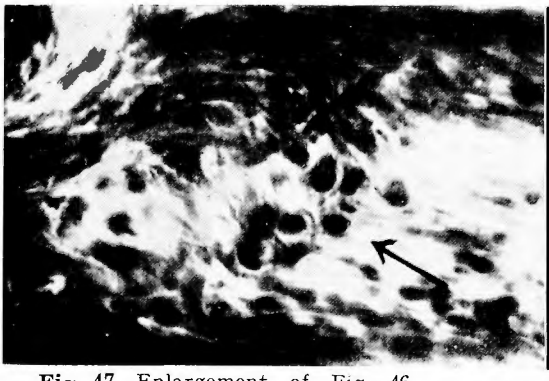

**Fig. 47** Enlargement of Fig. 46. Disappearance of nerve fibers and axons. ×400

**Fig. 48** Enlargement of Fig. 46. A indistinct figure of nerve cells and shrinkage of cytoplasma. ×900