主論文副第一部

ANATOMICAL AND HISTOLOGICAL STUDIES ON THE NERVE SUPPLY OF OESOPHAGUS OF CATTLE

The Research Department of Veterinary Science, the Post-graduate Training Course of Azabu Veterinary College
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I. INTRODUCTION

For the purpose of showing the peculiar organization and function of the ruminant oesophagus, author studied the nerve supply of the tube from the standpoint of morphology.

The oesophagus is a musculo-membranous tube being extended among pharynx and stomach, and it shows some differences in the functions of tube between mono-gastric and ruminants each other. In the mono-gastric animals there is only a main movement propelling the food from the mouth to the stomach. However, the oesophagus of ruminants, in addition to the primary deglutition, has the special function for involuntary rumination of the food once intaked in forestomach arised by the compound reflexion. These difference of the function of tube is caused by the structure of walls in the mono-gastric animals and ruminants.

Anatomical structures of the oesophageal muscle are quite differed from that of the skeletal muscles, as described by E.LAIMER (1883),[96] J.KAWAHARA (1924),[72] M.WEBER (1927),[72] S.SCHUMACHER (1927),[140] S.EURA (1930),[31] W.ELLENBERGER et H.BAUM (1932),[29] E.PERNKOPF et J.LEHNER (1937),[127] S.SISSON et J.D.GROSSMAN (1959),[146] etc. that the outer and inner muscle bundles, as a rule, are arranged spirally or elliptically, intercrossing dorsally and ventrally to the tube. Recently, T.MATSUI (1960)[105] found the presence of the remarkably corresponded muscle bundles (system) connecting the adjacent muscular layers in the mammalian oesophagus. T.FUJITA (1960)[33] described that this system is the structure of conducting impulse which is important for carrying on an orderly peristaltic movement of the digestive canal wall.

In addition to such interesting anatomical findings of the muscularis of oesophagus, the construction of muscularis in the ruminants varies from that of the mono-gastric animals. That is, in the oesophagus of mono-gastric animals, the muscular coat is consisted of the cross striated muscle in the upper half portion, while of the smooth muscle in the lower half portion of the tube. However, in the ruminants the muscular coat of whole oesophagus is constructed with the striated muscle. Author thinks that such appearance of function would be closely related to the constructive peculiarity of muscularis. In the contraction of the muscularis of ruminant oesophagus, there is a physiological function differed from that of the mono-gastric animals.

The innervation of the oesophagus of mono-gastric animals (horse, pig, dog, cat, rabbit, mouse, marmot, monkey and human being) have been studied by L.M.De WITT (1900),[22] N.P.SABUSSOW (1913),[136] R.GREVING (1931a),[43] T.SHIBA (1928),[145] T.ISSIKI (1928),[63] B.J.LAWRENTJEW (1928a and b),[100][101] T.KURE et al. (1929),[90] K.HARTING (1934),[48] H.SETO (1940),[143] M.ISHIZAWA (1936),[60] S.KIN (1937),[77] G.OTTAVIANI (1938),[126] T.KURE et al. (1939),[92] S.NOSE (1939),[119] T.SADA (1942),[137] S.FUKUYO (1943),[41] Ph. STOEHR (1949),[152] S.OKINAKA et T.NISHIMOTO (1951),[123] A.OTSU (1953),[125] N.TANAKA (1953),[154] G.SUGAMATA (1955),[153] T.YAMAMOTO (1960),[177] S.KAWATA et al. (1962a),[74] etc. anatomically, neuro-histologically, histochemically and physiologically. They have described the distribution of the autonomic, sensory and moter nerve terminations in the striated and smooth muscles individually and synthetically. On the other hand, the muscularis of ruminant oesophagus consisting of the complete striated muscle have been studied a little neuro-morphologically, in spite of the oesophageal muscle in mono-gastric animals mentioned above and the intramuscular nerve supply and termination in the limb muscles has been fully studied by many researchers. The nerve supply of the ruminant oesophagus (sheep and goat) have been described by A.CHAUVEAU et S. ARLOING (1873),[9] I.VAUGHAN (1908),[162] W.ELLENBERGER et H.BAUM (1932),[29] S.SISSON et J.D.GROSSMAN (1959),[146] Y.KATO (1961),[70] S.KAWATA et al. (1961),[73] S.KAWATA et al. (1962a),[74] S.YAMADA et al. (1962),[174] H.KIMATA et al. (1962),[76] S.YAMADA et al. (1964),[175] etc.. However, the histological study on the innervation of the cattle oesophagus have been reported only by S.KAWATA et al. (1961).[73] There are never seen any descriptions of the distribution of the autonomic nervous system in the cross striated muscle, except some reports of the sensory and moter innervation in the whole oesophagus. Namely, they did not prove the biological peculiarity as oesophageal striated muscle differed from the general limb muscles.

Author supposes that the muscularis of ruminant oesophagus have the characteristics as so-called visceral striated muscle resembling to the ocular and ear-ossicle muscles, as described by A.S.DOGIEL (1906),[23] J.BOEKE (1909, '27),[10] N.P.SABUSSOW (1913),[135] I.IWANAGA et al.(1923), B.J. LAWRENTJEW (1928a and b),[100][101] R.GREVING (1931b),[44] P.A.BERLENDIS et al. (1955),[5] D.W.BURNASCHOWA (1963),[17] I.NOJIRI (1963),[118] C.E.BLEVINS (1963, '64)[6][7] and the others, from the reason that it belongs to so-called visceral organ system, and then in the present research author tried to confirm the peculiarity of innervation in the oesophageal muscle differed from the muscles in torso and limbs, which will be described later. The oesophagus of ruminants was represented by the tube of cattle in this study.

Moreover, in the ruminant oesophagus the oesophageal papilla is formed on the surface of the mucous membrane of the pharyngeal end of tube, (H.WAKURI et al., 1961, '62)[168][169] while it is not formed in the mono-gastric animals. The nerve supply of such papilla of the ruminant oesophagus have been never investigated by the predecessors.

This time, author studied individually and systhetically the anatomical and histological features of the nerve supply of the cattle oesophagus. In this paper author is intending to describe the findings on the distribution of supplying nerves, features as so-called visceral striated muscle, movement of muscularis, proprioception, etc. in the cattle oesophagus in detail, including the nerve supply of the oesophageal papilla of the cattle.

The outlines of this study were already read at the 57th and 58th meetings of the Japanese Society of Veterinary Science.

II. EXPERIMENTAL MATERIALS AND METHODS

1. EXPERIMENTAL MATERIALS

The materials used for a systematic macro-anatomy of the supplying nerves of the oesophagus were four cows of about 8 month to 2,5 years aged after birth which were kept for experiment at the veterinary anatomical department of the Azabu Veterinary College.

For the neuro-histological observations of the nerve supply of the oesophagus, the materials totaled to 25 cases which were collected from the Shibaura- and Niitsu-City Slaughter House and Atsugi's Dairy Electric Center, including calves, young and adults. In the purpose to show the characteristic of the tube innervated mainly by the recurrent nerve, the histological specimens were cut out non-selectively from every parts in the upper half of oesophagus sagittaly, transversally and horizontally. Moreover, each specimens of the vagus, recurrent and sympathetic nerves were cut out at the level of about upper, middle and lower portion of neck and bottom of heart respectively.

2. EXPERIMENTAL METHODS

a) Methods of the macroscopical observation

The macroscopical observation of the supplying nerves of the oesophagus was firstly beginned to ascertain the origin of the vagus nerve, then it was proceeded to the branches derived from the vagus nerve in the guttural portion, the relationship between vagus and superior cervical ganglion, the returning way of the recurrent nerve, etc. in detail. Such observations of the supplying nerves of tube were carried out with the nacked eye. But sometimes the magnifying glass was used at the practical need, as the vagus nerve mingles complicatedly with the branches furcated from the glosso-pharyngeal and hypoglossal nerves at the ventral sides of the cranium.

b) Methods of the neuro-histological observation

Fixation : Materials cut from each cases were roughly fixed with 10 per cent neutral formol solution or 95 per cent alcohol for two weeks or more. The tissue specimens were carafully cut out non-selectively from the provisionally fixed materials, and refixed for 48 hours or more with the fresh fixative. D.BODIAN (1936)[8] described that the formalin fixed materials are generally susceptible for the silver imp-pregnation, as well as materials fixed with the CARNOY's alcohol-chloroform-acetic acid mixture. The excellent fact of 10 per cent formalin had been advocated by B.REXED (1948).[133] Accordingly, the most of materials were fixed with 10 per cent neutral formol solution for BODIAN's silver protargol method and FLETCHER's myelin technique. The alcohol fixed materials were used for CAJAL's silver impregnation method.

Embedding and Cutting : All the tissue specimens were dehydrate with alcohols and then embedded in paraffin. Sections were serially cut vertically or transversally towards the long axis of the tube with microtome into 15 to 20 micron thick. For the observation of the intermuscular and submucous plexuses, those were sliced horizontally or obliquelly.

Staining : The sections were stained mainly with BODIAN's silver protargol method, the type II method of CAJAL and FLETCHER's myelin technique. The outlines of each techniques are as follows.

(1). BODIAN's silver protargol method (D.BODIAN, 1936, 37)[8) 9)]

1) Remove the paraffin with xylol and run sections through absolute alcohol and 95 per cent alcohol. Wash in the distilled water.

2) Treat sections of formalin fixed materials for about 24 hours in a solution of 5 per cent glacial acetic acid. Wash in the distilled

water.

3) Place the sections in one per cent protargol solution containing 4 to 6 grams of metalic copper per 100 c.c. of solution ; 12 to 48 hours at 37°C. Wash in the distilled water. Use the protargol solution only once.

4) Place in reducing solution (below) for about 10 minutes.

1 gram	hydroquinone
5 grams	sodium sulphite
100 c.c.	distilled water

Wash throughly in the distilled water.

5) Tone in a solution of one per cent gold chloride, containing 3 drops of glacial acetic acid per 100 c.c. of solution ; 5 to 10 minutes. Section have a light purple color. This treatment is always neccessary. Wash in the distlled water.

If sections do not have a regular color, place in 2 per cent oxalic acid, until entire sections has a definite purplish color. Time is usually 5 to 10 minutes. Wash in the distlled water.

6) Remove residual silver-salts with solution of 5 per cent sodium thiosulphite ; 5 to 10 minutes. Wash throughly in the distilled water.

7) Dehydrate with alcohols, and mount in the balsam.

(2). Type II silver impregnation method of CAJAL (T.MIZUHIRA, 1959)[109]

1) Remove completely the alcohols of alcohol fixed tissue specimens. Do'nt wash with the water.

2) Place the specimens in a solution of 5 per cent silver nitrate

($AgNo_3$) for about 7 days at 35°C (dark).

3) Wash in the distilled water for about 2 minutes.

4) Place in reducing solution (below) for about 24 hours.

2 grams	hydroquinone
100 c.c.	distilled water
5 to 10 c.c.	formalin

5) Dehydrate with alcohols, embedded in paraffin, and serial sections.

6) Fixing, and gold-impregnation in a solution of next prescription for 15 minutes.

3 grams	hyposulphuric acid
3 grams	chromotrope 2R
100 c.c.	distilled water
5 c.c.	a solution of 0,1 per cent gold chloride

7) Wash throughly in the water for 30 minutes or more.

8) Dehydrate, and mount in the balsam.

The nervous elements have black or brownish black color, and other tissues have yellow or brownish yellow.

(3). FLETCHER's myelin technique (D.E.FLETCHER, 1947)[36)]

This is a modified method which was already, in 1922, reported by SPIELMYER.

1) Remove the paraffin with xylol, and run sections through alcohols, and wash in the distilled water.

2) Place the sections in a solution of 5,0 per cent iron alum [$NH_4Fe(SO_4)_2 \cdot 12H_2O$] for about 15 minutes. Wash in the distilled water.

3) Place in SPIELMYER's modified solution (below) ; 5 to 10 minutes at 55° to 60°C.

10 c.c.	10 per cent alcoholic hematoxylin solution
1 drop	ammonia solution (pharmacopoeia)
90 c.c.	distilled water

4) Tone in a solution of 5 per cent iron alum.

5) Wash throughly in the distilled water ; about 10 minutes. Dehydrate with alcohols, and mount in the balsam.

Myelin sheaths have a blue or light blue color and dark blue or dark purple in SCHWANN's nuclei.

(4). Other Staining

The sections were stained with hematoxylin and eosin for the research of the general histology. Moreover, in the preparations of silver impregnation, sometimes the argyrophillic connective tissue fibers are stained as well as the fine nerve fibers, therefore these sections were counterstained with a solution of one per cent aniline blue for identification of the nerve fibers.

c). Measurement

The size or thickness of the nervous elements was determined by measuring at the various parts using an ocular micrometer.

III. RESULTS

1. MACROSCOPICAL OBSERVATIONS OF THE SUPPLYING NERVES OF THE OESOPHAGUS

The distribution of the supplying nerves in the guttural and cervical portions of the oesophagus are about same between all cases and also between the left abd right sides of one case. The upper portion of the oesophagus of cattle is innervated by the vagus and sympathetic nerves. The distribution of those nerves shows the very complicated findings at the ventral part of the cranium, where they anastomose mutually with the branches derived from the glosso-pharyngeal and hypoglossal nerves. Fig. 1 shows a scheme of the distribution and mutural relation of the nerves in the guttural portion obtained by the present investigation.

The vagus is a mixed nerve, containing the sensitive, moter and parasympathetic characters. It is arised from the extensive region of the lateral side of the restiform body in the medulla oblongatae, closely behind the glosso-pharyngeal nerve nucleus. The vagus nerve passes the cranium through the foramen lacerum, and bears the rather large jugular ganglion on the lateral wall of the foramen. The ganglion nodosum of the cattle is absent at the original point of the superior laryngeal nerve. The superior cervical ganglion of the sympathetic nerve lies under the occipito-atlantal articulation.

This ganglion is elliptical form, and about 1,5 to 2,0 cm. in length. This is connected with the branches derived from both the glosso-pharyngeal and hypoglossal nerves, and also with the branch derived from the vagus nerve at nearly inner side of the bifurcation point of the occipital and internal maxillary arteries of the internal carotid artery. The vagus nerve unites with the cervical portion of the sympathetic nerve derived from the superior cervical ganglion, consequently it forms the vago-sympathetic trunk. However, the separation of those nerves can be done with ease. The vago-sympathetic trunk resulted by those fusion follows along the dorsal side of the common carotid artery. From the vagus nerve, the pharyngeal branch and the lateral, superior and inferior laryngeal, i.e. recurrent nerves are supplied to the pharynx and oesophagus respectively, as shown in Fig. 1.

The pharyngeal branch of the vagus nerve is most thick, and has the characteristic of sensory-moter. This branch is divided into two parts. The branch given to the oesophagus is large and passes backwards to the surface of the pharynx, joining with the communicative branches arised from the lateral and superior laryngeal nerves on its course, and its branch dividing into two parts. One of which reach to the commencement of oesophagus is insinuated between surface of tube and thyreoid gland, and furnishes some branches. Consequently, it forms a very rich nerve network with the arboraceous branches in the upper portion of the neck of the inferior laryngeal nerve. The lateral

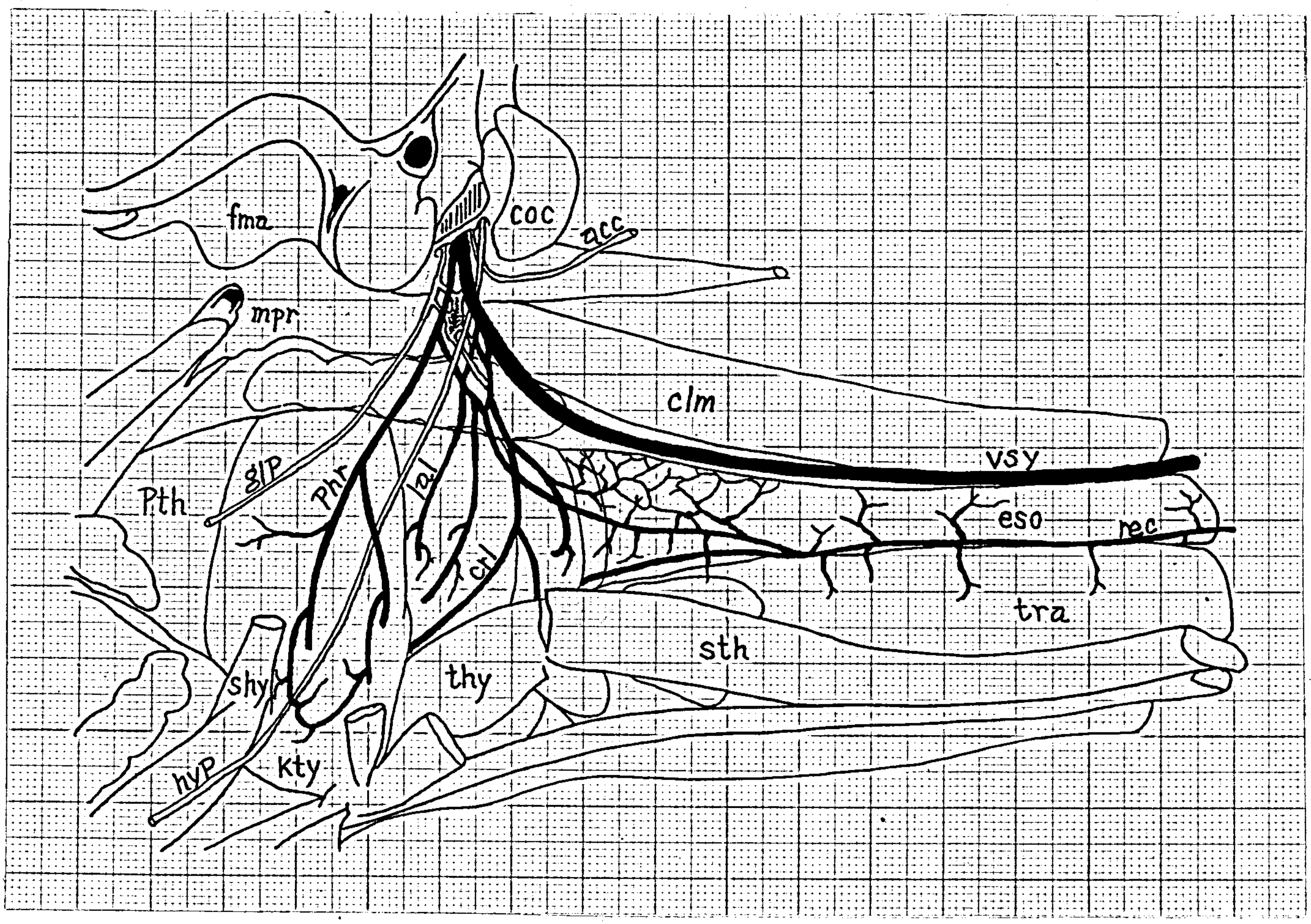


Fig. 1. A scheme showing the distribution of the supplying nerves on the left side of the pharynx and oesophagus of a cow. Detail shown in the text.

fma, Fossa mandibularis ; coc, Condylus occipitalis ; mpr, Processus muscularis ; shy, Stylohyoideus ; pth, Musculus palatopharyngeus ; kty, Keratohyoideus ; thy, Musculus thyreohyoideus ; sth, Musculus sternothyreoideus ; tra, Trachea ; eso, Oesophagus ; clm, Musc.longus capitis ; glp, Nervus glossopharyngeus ; hyp, Nervus hypoglossus ; acc, Nervus accessorius ; spotted part, Ganglion cervicale craniale ; vsy, Truncus vago-sympathicus ; phr, Ramus pharyngeus ; lal, Nervus laryngeus lateralis ; crl, Nervus laryngeus cranialis ; rec, Nervus recurrens laryngeal nerve exists only in the ruminants and is supplied to the thyreo-pharyngeal muscle. This nerve arises near above the superior laryngeal nerve, and on its course, receives a large branches derived from the glosso-pharyngeal nerve and another from the superior cervical ganglion. This also anastomoses with the branch originated from the pharyngeal nerve mentioned above. The superior laryngeal nerve is little more thick than the lateral laryngeal nerve. This branch rises below the preceding, receiving the lateral laryngeal, sympathetic and pharyngeal nerves, and passes backwards on the lateral side of the crico-oesophageal muscle (H.WAKURI et al., 1963a),[91] where it divides into two branches of the anterior and posterior. The posterior branch runs to the crico-oesophageal muscle and the upper end of oesophagus.

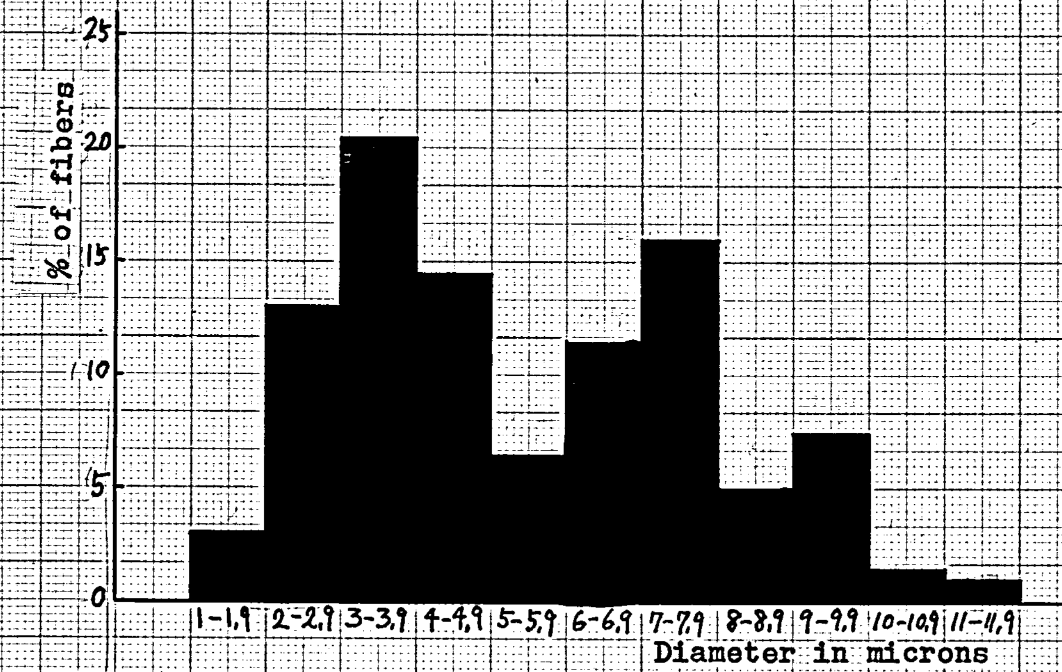
The vago-sympathetic trunk runs towards the thorax along the dorso-medial margin of the common carotid artery and the vagus separates from the sympathetic nerve at the lower end of the neck. These enters into the thorax passing the cranial thoracical aperture (Apertura thoracis cranialis), and then both the vagus trunk and the recurrent (inferior laryngeal) nerve receives the fine nerve bundles given by the cervico-thoracical ganglion (Ganglion stellatum). The inferior laryngeal nerve divides from the vagus trunk on the bottom part of heart in the thoracic cavity. The left and right inferior laryngeal nerves are not symmetrized in the their origins ; the right one turns around the costo-cervical artery, while the left one around the concavity of the aortic arch.

Each nerves supplies much branches to the whole oesophagus in the cervical portion, ascending the space between oesophagus and trachea, and divides into two branches of the dorsal and ventral at the upper end of the neck. The ventral branch passes towards the larynx at the inside of the crico-pharyngeal and crico-oesophageal muscles. The dorsal branch runs forwards on the lateral sides of the oesophagus, and again separates into two thin branches. The ventral branch anastomoses with the branch of the superior laryngeal nerve, and the dorsal branch communicates with the branch derived from the pharyngeal branch ; where it forms a very rich nerve network mentioned above. The terminal trunks of these nerves enters into the outer muscular layer after the repeated arborization in the outer connective tissue sheath of the oesophagus.

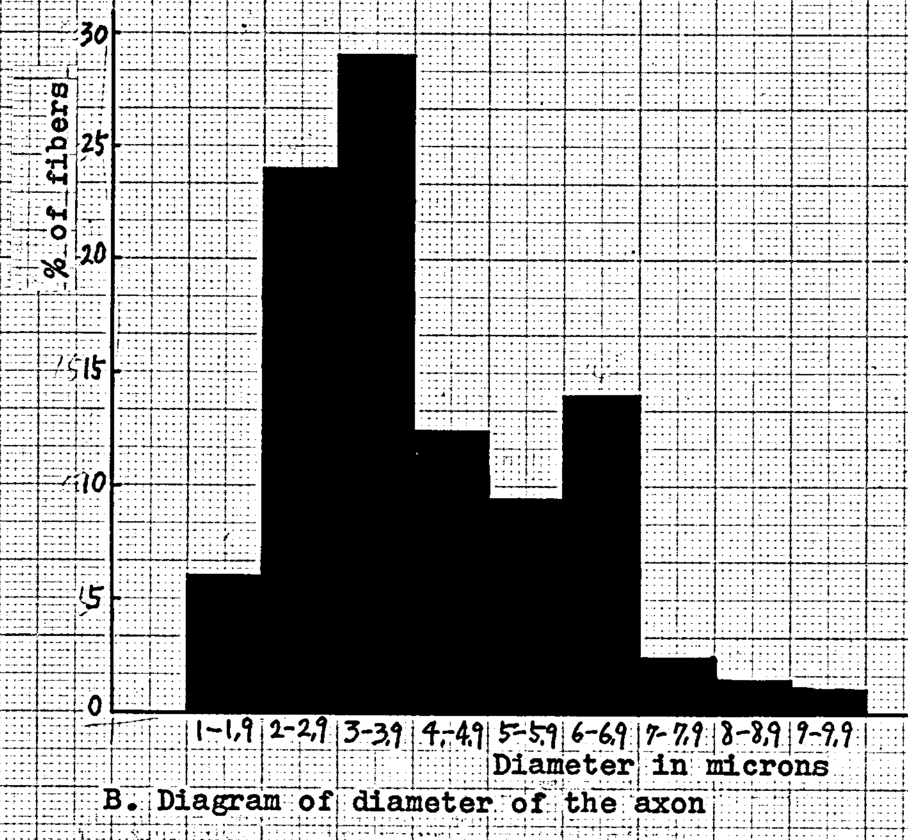
2. HISTOLOGICAL OBSERVATIONS OF THE SUPPLYING NERVES OF THE OESOPHAGUS

a) The vago-sympathetic trunk

The nerve trunk supplied the upper half of the cattle oesophagus is the vagus and sympathetic nerves. On the level of the middle portion of the neck, the cross section of the nerve trunk is showed in Fig. 5. Histologically, the thicker trunk of vagus and thinner one of sympathetic nerve are covered with the different capsules of the connective tissue. Accordingly, each trunk of the vagus and sympathetic nerves can be easily discriminated in the cervical portion of the cattle, as mentioned above. The thicker vagus trunk is consisted of about 50 nerve bundles which are covered with the perineurium. Each bundles are composed of about 4 to 7 thin bundles covered with the endoneurium. The thin nerve bundles are united with 20 or more nerve fibers in number. Fig. 6 shows a sagittal section of the vagus nerve. In the preparations of FLETCHER's myelin stain, the neuro-keratin structure of the medullated nerve fibers is observed clearly. Although it is difficult to obtain cross sections of all nerves throughout their entire course, it is possible to measure the diameters of nerve fibers at the specific points. Fig. 2-A shows the distribution of the maximum diameters of the myelin sheath of nerve fibers in the vagus cut at level of the upper portion of the neck. The diameters ranges 1,0 to 11,9 micron. The results are divided into main two peaks ; 2 to 4,9 micron for 47,5 per cent, especially includes the nerve fibers of 3 to 3,9 micron for 20,5 per cent within it, and 6 to 7,9 micron for 28,5 per cent, although there is a distribution of some nerve fibers (7,5 per cent) of 9 to 9,9 or more micron in diameter. In the preparations of BODIAN's silver protargol impregnation, there are seen the axons of the different size in diameter. (See Fig. 7) The measured values of these axons are given in Fig. 2-B. The range of axon population lies within 1,0 to 9,9 micron, and there are two peaks ; 2 to 3,9 micron for 53 per cent and 6 to 6,9 micron for 14



A. Diagram of diameter of the myelin sheath



B. Diagram of diameter of the axon

Fig.2. Caliber spectrum of nerve fibers of 10 nerves within the perineurium in the vagus nerve of a cattle

per cent. As shown in Fig. 2-B, the axons of 4 to 5,9 micron in diameter are evidently divided into two peaks, therefore larger axons of 5 to 6,9 micron in diameter amount to 23,5 in percentage.

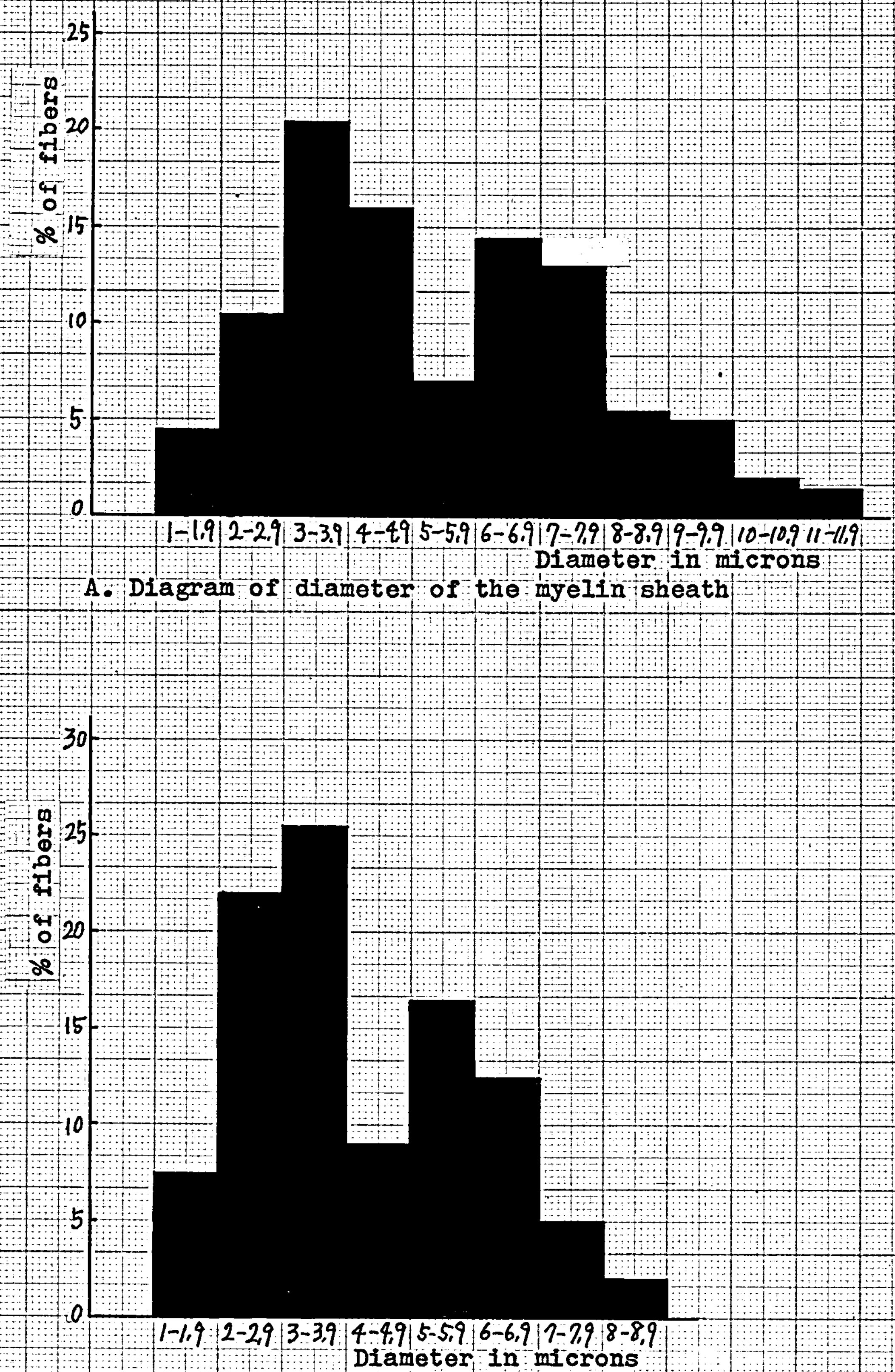
On the other hand, as shown in Fig. 5, the sympathetic trunk is consisted of about 10 nerve bundles in number. The sympathetic nerve is mostly constituted of a great number of non-medullated nerve fibers, except quite a little number of stout medullated nerve fibers. Fig. 8 shows the features of the sympathetic nerve fibers which shows never any neuro-keratin structures in the myelin stain.

Moreover, the vagus trunk has many nerve cells. Fig. 9 shows the nerve cells in the vagus trunk on the level of the upper portion of the neck. The nerve cells exist continuously with the nerve bundles of the vagus trunk, although sometimes independently. The nerve cells are mostly spheric or oval in form but semilunar or starform in small number, and has rarely a few or more neuro-plasmic processes. Accordingly, those would be mostly the unipolar, pseudo-unipolar or multipolar in their form. However, the multipolar nerve cell was a little in number. The nuclei of nerve cells are stained clearly and located in the central part of the neuroplasm, or rarely eccentric. The nucleus has the nucleoli from 1,0 to 2 in number. In section of middle portion of the nerve cell, the mantle cells arrange around the nerve cell, and those are counted about 20 to 23 in number. (See Fig. 10) Size of the nerve cells is 58,4 to 161,6 micron in range, 115,9 micron in mean. From these findings, it can be confirmed that the vagus nerve trunk is different from the sympathetic nerve trunk in its form.

b) Fiber-construction of the recurrent nerve

On the level of the middle portion of the neck, the cross section of the recurrent nerve is showed in Fig. 11. It is composed of about 10 to 13 nerve bundles covered with the perineurium. In the preparations of FLETCHER's myelin technique, the measured values of the maximum diameters of the myelin sheath of the nerve fibers are showed in Fig. 3-A. Their diameters range 1,0 to 11,9 micron. The peak of distribution is 2 to 4,9 micron for 47 per cent and 6 to 7,9 micron for 27,5 per cent, although there are a little nerve fibers of 8 to 11,9 micron in diameter. There also are the non-medullated fibers of very small diameter in this nerve, the values of which have not been included in Fig. 3-A. The measured values of the axon diameter in the preparations of BODIAN's silver protargol impregnation , as shown in Fig. 3-B, range 1,0 to 8,9 micron. 47,5 per cent of the nerve fibers measures 2 to 3,9 micron and 29 per cent of them measures 5 to 6,9 micron. Figs. 12 and 13 shows the distribution of the medullated and non-medullated fibers in the recurrent nerve.

3. HISTOLOGICAL OBSERVATIONS OF THE NERVE SUPPLY OF THE OESOPHAGEAL WALL



A. Diagram of diameter of the myelin sheath

B. Diagram of diameter of the axon

Fig.3. Caliber spectrum of nerve fibers of 5 nerves within the perineurium in the recurrent nerve of a cattle

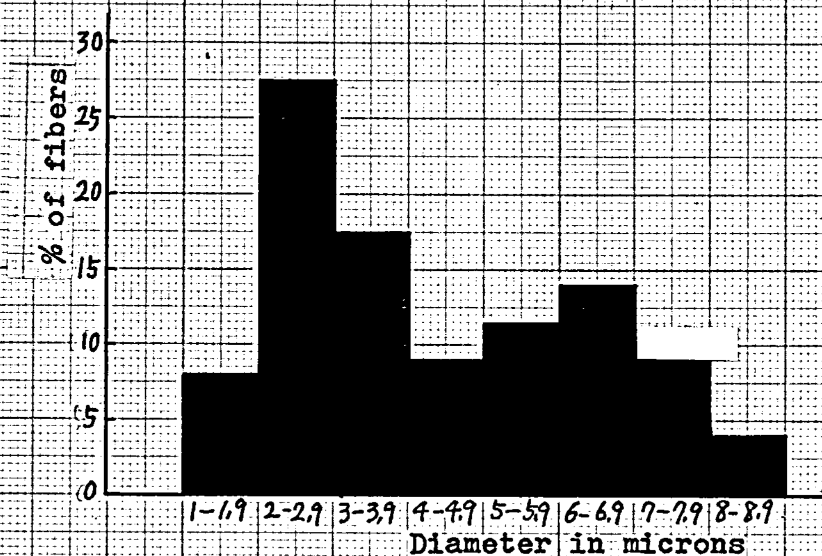
a) Nerve trunk in the outer connective tissue sheath

In the outer connective tissue sheath of the upper portion of the oesophagus, the nerve trunk fragments of various thickness derived from the recurrent nerve are frequently observed in the section. There are the rough nerve network formed by the nerve trunks in the outer connective tissue sheath. It is a so-called perimuscular nerve network. As shown in Fig. 14, the nerve trunks of the perimuscular network runs winding and including both the medullated and non-medullated nerve fibers. Figs. 15 and 16 shows a ganglion found in the outer connective tissue sheath on the level of the middle portion of the neck. The ganglion cells are counted about 20 in number. As shown in Fig. 17, there are the multipolar nerve cells. Each cell has a round or oval nucleus, a distinct nucleolus and granular and pigmented protoplasm. The ganglia also are sometimes found at the upper or lower portions of the neck. The ganglion cells will be classified into the most DOGIEL's type I and a few same type II by the arrangement and size of the neuraxis and dendritic processes.

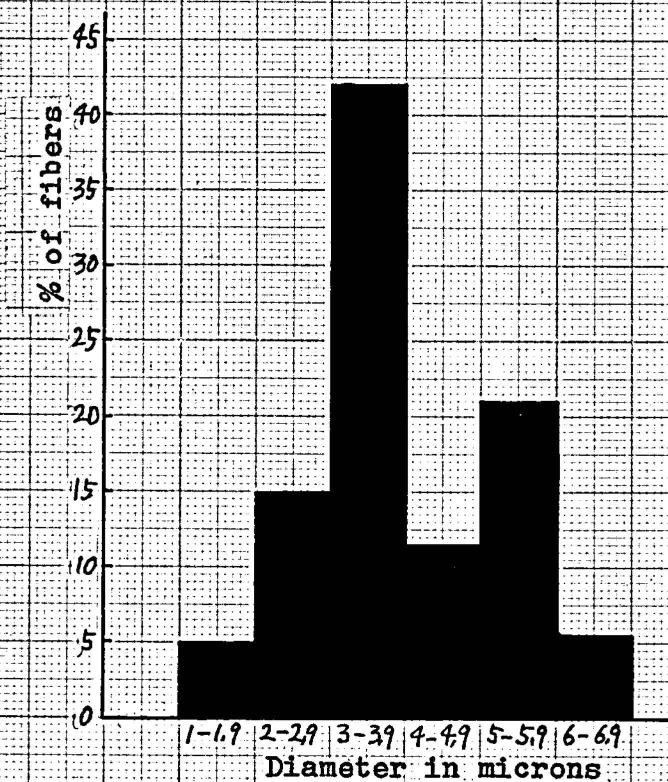
b) The nerve supply in muscular coat

(1). Intermuscular plexus

The muscular coat of the whole oesophagus of the cattle is consisted of the cross striated muscle. It is classified into two main layers by the lucent muscle membrane or the poor connective tissue. The intrinsic nerve trunks ramified from the nerve network in the outer connective tissue sheath penetrate the outer muscular layer, and frequently arborize on its course. (See Figs. 18 and 19) These nerve trunks forms a coarse meshed plexus between the outer and inner muscular layers. (See Fig. 20) Especially, the muscular layers forms the very irregular stratae between the crico-oesophageal muscle and the upper end of tube. As shown in Fig. 21, there are the formation of the triplicate intermuscular plexuses clearly. It shows the particular feature comparing with the intermuscular plexus in other places. Generally, the plane figure of the intermuscular plexus shows the network of the lozenge, trapezium or multifarious shapes. Moreover, in the upper portion of the neck, the fiber construction of 10 nerve trunks of intermuscular plexus shows in Fig. 4-A in the sections stained with FLETCHER's myelin technique. Range of the fiber population lies within 1,0 to 8,9 micron in diameter. Two peaks of the fiber population are 2 to 3,9 micron for 44,5 per cent and 5 to 7,9 micron for 36,5 per cent. There also are distributed much thin non-medullated nerve fibers which have not been included in this histogram. While the fiber construction of the intramuscular nerve originated from the nerve trunks of intermuscular plexus is given in Fig. 4-B. There are seen two characteristics of 2 to 3,9 micron (57 per cent) and 5 to 5,9 micron (21 per cent) in diameter except for the non-medullated fibers in the intramuscular nerve branch.



A. Diagram of diameter of nerve fibers in 10 trunk of the intermuscular plexus



B. Diagram of diameter of nerve fibers in 10 branches of the large intramuscular nerve

Fig.4. Caliber spectrum of myelinated fibers of the intrinsic nerves in the muscularis of cattle oesophagus

On the cross point of the nerve trunks of the intermuscular plexus, the ganglia are always formed. Rarely some ganglia are found within the outer muscular layer. (See Fig. 22) The ganglia in the middle and lower portions of the neck of the oesophagus are generally smaller, in number and size, than that in the upper portion of the neck. Figs. 16 and 23 shows a typical ganglion found at the nodal point of nerve trunks in the intermuscular plexus of the upper portion of the neck of cattle oesophagus. In the crossing section of the middle portion of the ganglion, there are grouped the nerve cells of about 20 in number. In addition, much small accessory cells are scattered between ganglion cells. In the present investigation there was never found any groups of ganglion cells of 30 or more in number. Generally, in the intermuscular plexus of the cattle oesophagus, the ganglion cells are grouped in number of about 5 to 25. The nerve cells are sometimes gathered at the regular place in a relatively large ganglion. However, there could not be observed the special relation in arrangement of the ganglion cells. The nerve cells are multipolar in form, and many of those will be classified into DOGIEL's types I and II cells by the arrangement and size of the neuraxis and many dendritic processes, although there are some young type. The neuraxis of nerve cell is long (See Fig. 24), and extends out one of the nerve trunks of plexus leading from the ganglion, usually as a non-medullated fiber. The medullated fiber found in the nerve trunks has no connection with the ganglion cells. As shown in Fig. 25, in the ganglion of intermuscular plexus of the cattle oesophagus, there is rarely observed the special findings that the thick nerve fibers runs the winding course showing the peculiar change in thickness, sending out the numerous branches in its course and shows the serpentine running to end in sharp points after losing the myelin sheaths. Moreover, as shown in Fig. 26, the nerve network (plexus) is formed around the blood vessels in the intermuscular connective tissue.

The nerve bundles originated from the nerve trunks of the intermuscular plexus, sooner or later, furcates repeatedly to terminate on the cross striated muscle tissue. Although there is well formed the delicate network with the terminal nerves in the intramurals, especially in the intramuscularis, as shown in Fig. 27, it, lately, becomes the terminal nerve stem fiber. Owing to the present research, author found clearly the autonomic (vegetative), sensory and moter nerve terminations in the muscular coat of cattle oesophagus, which will be described later.

(2). Autonomic nerve termination

The terminal nerve stem fibers are accompanied by little non-medullated nerve fibers. The non-medullated nerve fibers leave the stem fibers and arborize gradually towards the muscle fibers. (See Fig. 28) Fig. 29 shows the reticulated structure (terminal reticulum) formed of the finer nerve fibers which are found on the surface of the cross striated muscle fibers of the upper end of tube, especially in the crico-oesophageal muscle. It innervated the muscle fibers, closely contacting them. There are some special cell nuclei of the large oval or ellipse form. The cell nuclei are a little larger than SCHWANN's nuclei. The blood capillary in the muscle also receives the contact of the terminal reticulum of the autonomic nervous system.

(3). Sensory nerve termination

The sensory nerve termination was found on the level of the upper end of tube in general. The usual termination is the free type, and there also distributes sometimes the specialized types.

Free nerve termination : Figs. 30 and 31 shows the free terminations in the connective tissue found among the muscle fibers of the upper end of the cattle oesophagus. All the nerve fibers runs in the winding courses, showing a rather remarkable change in thickness, but they do not send out any side branches. The terminal axons are sharp. Some special cell nuclei are seen along the nerve fibers here and there. The sensory nerve fibers were counterstained with a solution of one per cent aniline blue to identify the argyrophillic connective tissue fibers. Such terminations are rarely found in the middle and lower portions of the neck of the tube.

Palisade-like termination : Fig. 32 shows a palisade-like nerve termination found at the end of muscle fiber of the inner muscular layer of the upper half portion of the cattle oesophagus. The size of the muscle fiber is equal to or barely thinner than that of the ordinary muscle fibers. A thick terminal medullated nerve fiber divides into two or more before joining to the muscle fibers. The myelin sheaths in these ramification are lost after having passed through the capsule of apparatus, and the axons run winding on the surface of the muscle fiber. There is the glia-like cells. In addition, some analogous terminations were found in the other instances, although it could not be confirmed the continuation between the terminal nerve fiber and the rounder on the apparatus. Moreover, no the muscle spindle was observed.

MEISSNER's corpuscle : Fig. 33 shows a terminal apparatus which well resembles the corpuscle of MEISSNER. It was found only in the inner muscular layer of the upper end portion of cattle oesophagus. This corpuscle is 50 x 250 micron in size and ellongated elliptical formation with rounded ends which is covered with the translucent connective tissue sheath. The medullated nerve fibers of 1,0 to 3 in number enters from the other end of corpuscle, where it loses the myelin sheath, and arborizes the some branches. The fine nerve fibers in the corpuscle serpentines between flat taste cells which lies within the apparatus.

(4). The size of moter unit

Although size of the moter unit must be calculate by ratio of the muscle fibers and nerve fibers in the muscularis of oesophagus, it is quite difficult in the practical research. In the present study it was conjectured from the following data. Fig. 34 shows an interesting arborization of the terminal nerve stem fibers diverging horizontally and radially into muscle. The terminal nerve stem fibers, therein, can be counted about 7 in number. Usually, each divergent nerve fibers, on its course, repeat the furcation more than twice. The furcation of a terminal nerve fiber also can be seen in Figs. 36 and 37. Fig. 35 shows three terminal nerve stem fibers furcated from the terminal nerve bundle. The terminal medullated nerve fibers derived from the terminal nerve fibers are innervated to the muscle fibers with the moter end plates. From these results, author estimated that the moter unit of oesophageal muscle of cattle is approximately 10 to 30 fibers in number. On the other hand, as shown in Figs. 44 and 75, the moter unit in the crico-oesophageal muscle of cattle has 4 or more fibers in number.

(5). Moter nerve termination

The moter nerve terminal apparatus is classified into two shapes ; types I and II. One of those (type I) has the ordinary features resembling morphologically to the moter end plate (" en plaque ") in the skeletal muscle fibers. It is formed everywhere in the oesophageal striated muscle of cattle. The other shape (type II) is the apparatus resembling to the moter end plate described by C.R.DUTTA et J.V.BASMAJIAN (1960)[26] and the others. It was found in the crico-oesophageal muscle, although it generally has the ordinary moter end plate.

Type I moter end plate : The oesophageal muscle of the cattle is generally endowed with a single end plate on the muscle fiber. There also was found a small number of multiple innervation forming the two or more end plates on a muscle fiber. Figs. 38 and 39 shows the typical features of the ordinary moter end plate found in the cross striated muscle of cattle oesophagus. Owing to the data obtained from light microscopy, it is impression that much more than approximately 60 per cent has the ordinary moter end plate. Single terminal nerve fibers of 2 to 4 or more micron leading to the moter end plates are characteristically short, often passing over more than two or three muscle fibers before forming terminal arborizations. The moter end plate was located near in the middle part of the cross striated muscle fibers, namely, it is a simple innervation. The proper amount of so-called multiple (double) innervation in the oesophageal muscle of cattle, as seen in Figs. 40, 43 and 74, was found at the upper half portion of tube. There exists an ordinary end plate and a simple accessory end plate, and these are innervated by an unitary nerve fiber. The distance between two moter end plates ranges 60 to 150 micron. Figs. 41, 42 and 73 shows two nerve fibers in an ordinary moter end plate. Relatively thick one is the ordinary moter nerve fiber of 2 to 4 or more micron in diameter, and the other is thinner than the ordinary thick fiber. This finding differs from the multiple innervation mentioned above clearly, although they have a similarity of histological appearance each other. The thin nerve fiber is called the accessory or secondary fiber by previous authors and it forms a simple small end plate. The moter end plates accompanied by the accessory nerve fiber are evently found at the whole upper half portion of the oesophagus. The thin fiber shown by the arrow in Figs. 43 and 74 is the ultraterminal nerve fiber. This nerve fiber forms the ultraterminal end plate on a different muscle fiber. In addition, it was rarely found the triple innervation endowing the three end plates, as a total, on a muscle fiber. Namely, the " terminaison en grappe " found in the oesophageal muscle of the cattle was so rare, as shown in Figs. 37 and 72.

As a rule, both the moter end plate in the simple or multiple innervation and the end plate accompanying by the accessory nerve fiber have the similar feature neuro-histologically. Those detailed feature is invariably characterized as the following descriptions. (See Figs. 38 and 39) The ordinary moter end plate shows the oval or ellipse form in outline, and measures 15 x 25 to 40 x 65 micron in dimension ; 30 x 50 micron on an average. The terminal medullated nerve fiber attached near to the moter end plates penetrates through the sarcolemma after losing the myelin sheath, and the axon immediately arborizes into 3 to 4 in number in an end plate. The axonal arborizations are mostly ended in sharp points. The periterminal network in the moter end plate was rarely recognized in the preparations of BODIAN's silver super-impregnation. The oval or ellipsoid nuclei in the moter end plate assembles in number of 6 to 9, 8 on an average in a poor sarcoplasm. There are formed so-called DOYERE's eminence unappearantly. These nuclei are stained coarsely. The accessory end plate in both the multiple (double) innervation and accessory nerve fiber has so simple in structure, that it has only 2 to 3 terminal arborization and 2 to 4 nuclei. (See Figs. 40, 42, 72, 73 and 74)

Type II moter end plate : In the crico-oesophageal muscle of the cattle, the type I moter end plates are formed usually, besides, the type II moter end plate (bajonettartige Apparate), as shown in Figs. 44 and 75, is rarely found therein. It is an end plate, where the about 4 terminal nerve fibers ramified from the terminal nerve stem fiber ends on the muscle fibers with the plump point or very minute dispersion. The relationship between the oval nuclei located around the plates and the axons could not be disclosed in detail. Moreover, one of the terminal ramification in this end plate anastomoses with a fine nerve fiber come from the different direction. Author should like to believe that it would be an accessory nerve fiber.

c) Nerve supply in the submucous tissue

In the submucous tissue of the upper end of cattle oesophagus, the submucous (MEISSNER's) plexus is well developed. It is formed far poorly in the middle and lower portions of the neck. The major portion of the submucous plexus lies closely to the inner muscular layer. Author found the large ganglia in the submucous tissue of the upper end of the tube, as shown in Fig. 45. The size of the ganglion cells is smaller than that it in the outer connective tissue sheath and intermuscular plexuses. There are some multipolar ganglion cells. That is, some nerve cells belong to the DOGIEL's type I cell, while many of those to the DOGIEL's type II cell and young type or smaller nerve cells. The nerve cells are counted about 10 to 20 in the cross section of the middle part of the ganglion. Fig. 46 shows the fragments of the submucous plexus found at the oesophageal vestible of the cattle and also a detected ganglion. The ganglion cells, as shown in Figs. 46 and 47, are classified into two types ; argentophile and argentophobe nerve cells.

The oesophageal gland is well developed in the vestible, as shown in Figs. 46 and 48. There are the thick nerve fibers in the gland tissue. (See Fig. 48) By the observation of the section, the formation of the rough nerve network (periductal plexus) is recognized around the glandual ducts. (See Figs. 49 and 50) The thick nerve fibers in Figs. 49 and 51 are the sensory. One of those enters into the small gland tissue and the other ends sharply in the connective tissue of the circumference of the duct. (See Fig. 51) The intraductal nerve fiber was not found. As shown in Fig. 52, the fibers are richly distributed around the terminal portion of the gland tissue. Some nerve fibers are terminated freely around the gland cells.

In the submucous tissue of the middle and lower portions of the neck of cattle oesophagus, the nerve supply is poorer than in the oesophageal vestible and the upper end of the tube. As shown in Fig. 53, in the upper portion of the neck, there are supplied the thick nerve fibers of the fragments of the submucous plexus. They run in parallel with the surface of the mucous membrane. Many of nerve stem ramifications originated from the plexus runs towards the lamina propria accompanying by the blood vessels. (See Fig. 54) The nerve supply of the lamina muscularis mucosae could not be studied in detail. The distribution of the medullated nerve fiber was not recognized therein.

d) Nerve supply in the mucous membrane

The nerve supply in the lamina propria is usually poor except in the oesophageal vestible. The nerve stem fibers which originated from the submucous plexus, as shown in Fig. 55, includes two types of the argentophile and argentophobe fibers. The argentophobe nerve fibers should be considered the fine fibers of the autonomic nervous system, but no the terminal reticulum was recognized in detail. Figs. 56 and 57 shows the fragments of the network in the lamina propria of the upper portion of the neck of oesophagus. There are many fine nerve fibers, few thick nerve fibers accompanied by them. Thick argentophile nerve fibers are terminated near by the lamina propria or papilla of connective tissue. Fig. 58 shows the simple serpentine thick nerve fiber found on the level where the oesophageal papilla exists. It has some SCHWANN's nuclei and terminates in sharp point. Fig. 59 shows the simple peculiar serpentine nerve fiber in the lamina propria of the upper portion of the neck. Its terminal end does not show any perceptible difference in thickness. Figs. 60 and 61 shows the nerve fiber foraied into the papilla of lamina propria in the upper and middle portions of the neck. It reaches mostly the tops of papillae without the myelin sheaths. The nerve supply in the oesophageal vestible of cattle is well developed, as shown in Figs. 62 and 63. The nerve fiber terminates rarely in the lamina propria. On the observation of the section, it is supposed that the formation of the mucous plexus will exist.

The nerve fiber in the mucous epithelium was detected in the oesophageal vestible of the cattle. Fig. 62 shows the fine nerve fiber in the epithelium originated from a nerve stem fibers of the mucous plexus. Fig. 63 also shows the intraepithelial nerve fiber in about same place. The terminal end of the nerve fiber is knobbed. The intraepithelial nerve fiber in the upper portion of the neck was found in the young cases. (See Fig. 64) These nerve fibers in the epithelium run in more or less winding courses between the epithelial cells.

4. NERVE SUPPLY OF THE OESOPHAGEAL PAPILLA

In the oesophageal papilla of the cattle, the nerve supply is poor in both the adults and young cases, although there are the some thick nerve fibers and special nerve cells. The nerve fiber in the lamina propria of the oesophageal papilla runs along with the blood vessel or capillary in general. Fig. 65 shows the typical histological features of the oesophageal papilla of adult cattle. Figs. 66 and 67 shows the simple serpentine nerve fibers in the lamina propria of the oesophageal papilla. The nerve fibers show some perceptible differences in thickness. There are rarely recognized the simple branched nerve fiber provided with a conspicuous varieties in thickness. Fig. 68 shows the serpentine nerve fibers, lying beneath the epithelium, with some perceptible differences in thickness, and its tip enters into the secondary papilla. Fig. 69 shows the fine nerve fibers in the secondary papilla. These fibers terminate sharply with a winding courses. Moreover, as shown in Fig. 70, the special nerve cells are scattered in the lamina propria. Generally, these nerve cells are located around the blood vessels and form the extensive network by the junctions of the axis cylinder processes of the nerve cells. In the oesophageal papilla of the calves, the secondary papilla do not develop throughly, therefore, the nerve supply is simple. That is, Fig. 71 shows two rather simple nerve fibers in the lamina propria. The special nerve cell was not observed in the lamina propria of the young cases. The intraepithelial nerve fiber was not detected in the oesophageal papilla.

IV. DISCUSSIONS

1. THE SUPPLYING NERVES OF THE CATTLE OESOPHAGUS

The macroscopical findings of the supplying nerves of cattle oesophagus generally coincide with the descriptions of the preceded workers. The nodosal ganglion is absent in cattle. Same finding, in literature, already have been described by A.CHAUVEAU et S.ARLOING (1873),[9] Y.KATO (1961).[70] However, W.ELLENBERGER et H.BAUM (1932)[29] and S.SISSON et J.D.GROSSMAN (1959)[146] described that the plexus nodosus or ganglion nodosum is formed at the beginning point of the superior laryngeal nerve.

At the upper end of the oesophagus, there are supplied with the pharyngeal branch and superior laryngeal nerve derived from the vagus. The pharyngeal branch is a very voluminous nerve, as described by A.CHAUVEAU et S.ARLOING (1873),[9] I.VAUGHAN (1908)[162] and S.SISSON et J.D.GROSSMAN (1959).[146] One derived from the pharyngeal branch is sent to the oesophagus. This small branch is named the oesophageal branch of the pharyngeal nerve by A.CHAUVEAU et S.ARLOING (1873).[9] H.KIMATA et al. (1962)[76] studied the distribution and supplying areas of the vagus nerve in the goat oesophagus. Namely, they described that the superior laryngeal nerve innervates the cervical portion of the goat oesophagus and the oesophageal branch of the recurrent nerve innervates at the area from the bottom of the heart to the upper part of the neck, functioning the contractoric peristalsis of the tube. R.W.DOUGHERTY, R.E.HABEL et H.E.BOND (1958)[25] studied experimentally the supplying areas of the moter nerve in the oesophagus, using the decerebrated sheep. The results are about same to the findings described by H.KIMATA et al. (1962).[76] Author decided that the supplying areas of the superior laryngeal nerve in the oesophagus of the goat and sheep are a little more expanded than in the cattle. A.CHAUVEAU et S.ARLOING (1873)[19] described that the oesophageal branch of the pharyngeal nerve anastomoses with the branches derived from the inferior laryngeal nerve in the upper end of the oesophagus, where it forms a very conspicuous nerve network. According to the results of the present investigation, such nerve network was well developed in the area from the crico-oesophageal muscle (vestible) to the oesophageal papilla in the ring of muscle at the upper end of the tube. In the middle and lower portions of the neck of the oesophagus, the formation of the nerve network is very poor. The terminal nerve trunks originated from the nerve network in the outer connective tissue sheath are immediately entered into the muscular coat.

The vagus nerve in the cervical portion is accompanied by the sympathetic nerve covering with the different connective tissue sheath. N.TANAKA (1953)[154] described that the vagus trunk of the dog joines with the sympathetic trunk so that it is difficult to separate them in the cervical portion. In the cattle the separation is very easy, as in the horse. The fiber construction of the vagus nerve of cattle is complicated as seen in Figs. 2-A and B. The distribution of medullated nerve fibers has two main peaks of 2 to 4,9 micron for 47 per cent and 6 to 7,9 micron for 28,5 per cent, while 10 per cent of the nerve fibers measures 9 to 9,9 or 11,9 micron in diameter. The thin non-medullated nerve fibers were not researched in the preparations stained with FLETCHER's myelin technique. Author guess that a very small number of the thin non-medullated nerve fibers may be included in the thin diameter fibers of 4,9 or 3,9 to 2 or less micron of the histogram of Fig. 2-B. Namely, there are seen the distribution of both the medullated and non-medullated nerve fibers. T.IWANAGA (1961)[66] described that the medullated nerve fibers of vagus of the crab-eating monkey (Macaca irus) are 6,017 as a sum total. In the vagus nerve of cattle, the number of the medullated fibers is calculated by the findings mentioned above that it is far greater than that of the crab-eating monkey's vagus, although quantitative discussion of the nerve fiber was not performed in present research. According to D.E.HILLMAN et J.J.TAYLOR (1963),[52] they described that the neuro-keratin structure of the medullated nerve fiber is a product which is originated from the destruction of the fiber, although it consist of the reticular framework of neuro-keratin and spaces. M.NAKANISHI et C.R.RI (1934)[116] described that both the thin medullated (2,5 to 5 micron) and thick medullated nerve fibers are included in the vagus nerve of the cervical portion of the rabbit oesophagus. In the vagus of cattle, the relatively thick nerve fibers (6 to 7,9 or more micron) is about 35 per cent in frequency. (See Fig. 2-A) According to T.KURE (1931),[91] the thick medullated nerve fiber in the vagus trunk enters almost into the recurrent nerve.

T.SHIBA (1928)[145] described that the nerve fiber of 3 or less micron in the vagus are the autonomic (parasympathetic) fibers in the dog.

The presence of the nerve cells in the vagus trunk have been noted by H.E.BROWN (1935),[16] B.DOLGO-SABUROFF (1937),[24] S,NISHI (1949),[117] S.OKINAKA et T.NISHIMOTO (1951),[123] etc.. The nerve cells in the vagus trunk of cattle varies from spheric or oval to semilunar or stellar in form. Namely, their shapes were the unipolar, pseudo-unipolar or multipolar. T.ITO ēt M.HATA (1958)[63] reported the occurrence of vacuole-containing ganglion cells in the ganglion nodosum of the vagus nerve of rodents. However, no such vacuolated cell was observed in the nerve cell of the vagus trunk of the examined cattle. The nerve cells are distributed mostly on the level of the upper two-thirds of the cervical portion of the tube. According to S.OKINAKA et T.NISHIMOTO (1951),[123] the nerve cells in the vagus trunk of ~~the~~ dog is mostly in the lower half portion of the neck, moderately in the upper half portion of the neck, very poorly in the thoracical portion and absent in the abdominal portion. Moreover, they said that the nerve cells in the vagus trunk relates with the efferent autonomic nerve fibers ; perhaps they would have the nature of the parasympathetic nervous system. S.NISHI (1949)[117] also described the similar opinion. There also may be included the sympathetic nerve fibers, because that the recurrent nerve receives the nerve fibers derived from the cervico-thoracical ganglion. Thus, author considered that the nerve cells in the vagus trunk belongs to the autonomic system, from their morphological features, as described by Ph.STOEHR (1922),[149] O.KROELLING et H.GRAU (1960)[82] and the others that the unipolar or multipolar nerve cells in the peripheral nerves has the characteristics of autonomic nerve system.

More significant nerve in the cattle oesophagus is the recurrent nerve functioning the rumination. The feature of the fiber construction is seen in Figs. 3-A and B. That is, as shown in Fig. 3-A, range of the nerve fibers lies within 1,0 to 11,9 micron in diameter, and there are seen two peaks, 2 to 4,9 micron for 47 per cent and 6 to 7,9 micron for 27,5 per cent. In addition, the non-medullated nerve fibers are evidently distributed in the recurrent nerve, although a small number of it lies within the nerve fibers of 3,9 to 2 or less micron in diameter in the histogram of Fig. 3-B. In literature, S.KIN (1937)[77] described that the fiber construction of the recurrent nerve of the cat and rabbit is composed of three main groups ; the medullated fibers of 2,5 to 5 micron in diameter, the densely stained thick cranial medullated fibers and a small number of non-medullated fibers. He also described that the thin medullated nerve fibers have the charactereristic of the autonomic nerve. The analytic study of the recurrent nerve in the crab-eating monkey have been carried out by T.IWAYAMA (1961)[66]; a total number of the medullated nerve fibers is 2,698 on an average, and distribution curve of the diameters of the nerve fibers shows two peaks between 3 to 4 micron and 10 to 12 micron respectively. The fiber construction of the recurrent nerve of cattle is mostly resembled to the results of the cat and rabbit described by S.KIN (1937).[77] The thick medullated fibers of 10 to 11,9 micron in diameter were included about 3,5 per cent in frequency, and differed from the results in the monkey. From the results obtained in the present study, author should like to guess that large number of the medullated nerve fibers in the recurrent nerve is the cranial nerve fibers, considering the characteristics of fiber construction of the vagus described above, and the nerve fibers of 3,9 micron or less in axon diameter have the characteristics of the autonomic nervous system.

2. THE NERVE SUPPLY IN THE OESOPHAGEAL WALL

a) Intramural plexus

The rough nerve network is formed in the outer connective tissue sheath, and the nerve trunk fibers are always wound in their course. J.NAKAI (1952)[111] described that the winding courses of the peripheral nerve fibers are the defensive phenomenon to be aggainst to the mechanical extension of the nerve. There are the ganglion in the cross or ramose points of the nerve trunk. Most of the ganglion cells are multipolar and have many dendritic processes and one neuraxis. However, S.KAWATA et M.OKANO (1961)[72] described that the ganglion includes the bipolar nerve cells.

The intermuscular and submucous plexuses in the oesophageal wall corresponds to the AUERBACH's and MEISSNER's plexuses in the gastric and intestinal wall respectively, as described by Ph.STOEHR (1922),[149] E.KLEIN (1928)[79] and the others. R.GREVING (1931b)[44] described that the intermuscular plexus of the cat oesophagus well develops in the smooth muscular coat of lower half portion, but it is unconspicuous in the striated muscular coat of upper half portion. However, the intermuscular plexus and ganglion cells in the cattle were comparatively developed, in spite of the muscular coat of whole oesophagus is constructed with the striated muscle. Generally, the nerve bundles originated from the intermuscular plexus innervates to the outer and inner muscular layers and blood vessels. The triplicate intermuscular plexuses are formed between crico-oesophageal muscle and the beginning point of proper muscularis of the cattle oesophagus, especially at the junction of the pharynx and oesophagus. This structure is related to the function, under which the muscular coat in this part may contract skillfully to send the ingested food down smoothly. The intrinsic nerve trunk penetrating the outer muscular layer is sometimes arborized on its course. This is an interest anatomical finding, from the standpoint of the nerve supply of the muscular layers. Many ganglia exist at the cross or ramifying points of the nerve trunks of plexus in the upper portion of the neck. Most of the ganglion cells are related to the autonomic nervous system which will be described later. According to L.M.De WITT (1900),[22] in the oesophagus of rabbit and in the upper part of the oesophagus of cat, the ganglia are much smaller and less frequent and contain few nerve cells. T.KURAMOTO (1957)[88] described that in the oesophagus of human being, many of the nerve cells exists in the pharyngeal end, few in the middle portion and very rare in the cardiac portion. On the number of the nerve cells, R.GREVING (1931a)[43] described that the maximal number of the nerve cells in the intermuscular plexus is 40 in the human oesophagus. T.SADA (1942)[137] described that the ganglion cells in the human oesophagus are grouped 10 to 20 in number, while, rarely, a ganglion cell exist independently. N.P.SABUSSOW (1913)[135] found the groups of 2 to 10 in number in the ganglia of the intermuscular plexus in the oesophagus of dog, cat and rabbit. B.J.LAWRENTJEW (1929)[102] reported that the ganglion cells in the intermuscular plexus of the dog oesophagus are grouped 10 to 60 in number in general. The number of the ganglion cells in the cattle oesophagus coincides with the results of N.P.SABUSSOW (1913)[135] and T.SADA (1942)[137] in general.

The ganglion cells of intermuscular plexus are multipolar, as described by Ph.STOEHR (1922)[149] and the others, and classified into DOGIEL's type I and II cells in the adult cattle. Although M.ISHIZAWA (1952)[62] described that the type differentiation of the ganglion cells is very difficult to classify by the arrangement of their nerve processes. The histological features of each type are as follows. Namely, the neuro-plasmic processes of DOGIEL's type I cell penetrates the capsule of mantle cells, but in same type II cell the neuro-plasmic processes are short, especially the dendritic processes are not passes the capsule of mantle cells. The former corresponds to the type III described by Ph.STOEHR (1922),[149] while his type I in the latter. According to Ph. STOEHR, jr. (1932),[150] K.A.REISER (1932),[130] T.YOSHITOSHI (1941),[178] H.KUMAGAWA (1941),[86] T.SADA (1942),[137] T.SATO (1949),[138] etc., many of the ganglion cells in the wall of alimentary tracts are DOGIEL's type I cell, and the same cell of type II is found only rarely. B.J.LAWRENTJEW (1929),[92] R.GREVING (1931a),[43] T.TOYOTA (1955),[159] G.SUGAMATA (1955),[153] T.WADA (1958b),[166] Y.BABA (1961),[3] etc. reported the similar findings in the oesophageal, gastric and intestinal walls of goat, dog, cat, rabbit and hedgehog. T.OHI (1954)[121] described that the dendritic processes of the ganglion cells in the gastric wall of white mice are so poor in development, therefore, it is impossible to make the classification of nerve cells. The young type of the nerve cells, which their nerve processes can't be made out quite so clearly, were moderately recognized in the oesophagus of young cattle and calves.

S.KAWATA et M.OKANO (1961)[73] described that the submucous plexus is not formed in the submucous tissue of the cattle oesophagus. A.KUNTZ (1947)[87] and N.TANAKA (1953)[154] found no ganglia in submucous plexus of the oesophagus of dog, human being and the other mammals. Author found the formation of the submucous plexus and ganglia in the cattle oesophagus. The nerve trunk fibers originated from the sub-

mucous plexus are innervated on the submucous tissue and mucous membrane. The existence of the ganglion cells in the submucous plexus are detected by L.M.De WITT (1900),[22] N.P.SABUSSOW (1913),[135] B.J.LAWRENTJEW (1929),[102] G.SUGAMATA (1955),[153] S.KAWATA et al. (1962a and b),[73) 74] etc. in the oesophagus of horse, goat, dog, cat and rabbit. B.J.LAWRENTJEW (1929)[102] described that the ganglion cells are grouped 2 to 10 in number at the cross points of the nerve fibers bundles in the submucous plexus.
In the human being, M.ISHIZAWA (1936, '51),[60) 61] rarely recognized them in the section preparations of hematoxylin and eosin stain. T.SADA (1942)[137] reported that the ganglion cells are generally gathered in a few number or to ten, but rarely only one. The discrimination of the ganglion cell type in cattle is about same to the description of R.GREVING (1931a),[43] K.A.REISER (1932),[130] Ph.STOEHR,jr. (1932, '39),[51) 52] T.SADA (1942),[137] etc.. Such two types also were classified by R.HONJIN (1951),[55] R.HONJIN et al. (1958),[56] T.WADA (1958b, '59)[165) 166] and Y.BABA (1961)[3] in the ganglia of the intestinal walls of goat, cat and mouse and by T.WADA (1958a)[165] and T.NAKAMURA (1960)[113] in the ganglia in the submandibular and sublingual glands of cat and mouse respectively.
R.HONJIN (1951)[55] described that the neuraxis of the argentophile nerve cell forms the associated neuron among respective ganglia and ends around the argentophobe nerve cells. He said that the argentophobe nerve cell becomes the starting point of the syncytial terminal reticulum in the autonomic nervous system.

Refered to the nerve supply of the lamina muscularis mucosae, S.W.RANSON et P.R.BILLINGSLEY (1918),[129] N.TANAKA (1953)[154] and T.KURE et S.OKINAKA (1956)[95] described that the medullated nerve fiber of the submucous tissue is not supplied in the muscularis mucosae, because it is the smooth muscle.

The mucous plexus in the lamina propria is clearly formed in the vestible and upper end of the cattle oesophagus. This corresponds with the subepithelial plexus in the superficial zone of the lamina propria of the human oesophagus described by M.ISHIZAWA (1951).[61] L.M.De WITT (1900)[22] described that under the epithelium, the medullated nerve fibers lose their myelin sheaths and form a fine reticulated subepithelial plexus, of which fibers extend in long distance under the epithelium. T.WADA (1959)[167] found the mucous plexus in the cat stomach.

Moreover, the complex nerve network is formed with the terminal nerve fibers in the muscularis of cattle oesophagus, as shown in Fig. 27. According to F.FROHSE (1898),[37] there is formed the compound nerve plexus in the various skeletal muscles of the human being. W.FEINDEL, J.R.HINSOW et G.WEDDELL (1952)[33] described the complex network forming with the terminal nerve bundles in the general skeletal muscles. These descriptions resembles to the finding of nerve network in the oesophageal muscle of cattle. The terminal nerves in the network includes both the thick medullated fibers and the thin nerve fibers. These nerve fibers, as mentioned above, are derived from the supplying nerves of the oesophagus. The feature of fiber construction of the intrinsic nerves, as seen in Fig. 4-A, has two peaks of 2 to 3,9 micron for 44,5 per cent and 5 to 7,9 micron for 36,5 per cent. In the intramuscular nerve fibers, as shown in Fig. 4-B, 57 per cent measured 2 to 3,9 micron and 21 per cent measured 5 to 5,9 micron in diameter. In literature, according to D.BARKER (1948)[4] and L.E. HAGBARTH et G.WOHLFAST (1952),[47] the thickness of the sensory nerve fibers entering into the sensory terminations lies between 6 to 12 micron or 8 to 15 micron in diameter. C.E.BLEVINS (1964)[7] described that it governs the moter end plate by the nerve fibers of 2 to 4 micron in diameter. Provisionally, for the quantitative discussion of innervation, as a standard to those values, the ratio of two peaks of the nerve fibers in oesophageal muscle is mostly corresponded to the quantitative rate both the sensory and moter innervations.

These nerve fibers runs into the muscularis and mucous membrane for formation of the respective nerve terminal apparatus, including the autonomic nerve fibers which is not added in Fig. 4.

b) Autonomic innervation

The distribution of the autonomic nerve in the cross striated muscles of the mammalian oesophagus have been confirmed by T.ISSIKI (1928),[63] T.SHIBA (1928),[145] T.KURE et al. (1929),[90] T.KURE (1931),[91] R.GREVING (1931a),[43] T.KURE et al. (1939),[92] T.SADA (1942),[137] Ph.STOEHR,jr. (1949),[152] S.KAWATA et al. (1961),[73] S.YAMADA et al. (1962),[174] H.KIMATA et al. (1962)[76] and S.YAMADA et al. (1964)[175] histochemically and neurohistologically. The distribution of the autonomic nervous system in the cattle oesophagus is elucidated by the presence of the sympathetic nerve fibers derived from the superior and inferior cervical ganglia and the efferent autonomic nerve fibers being originated from the nerve cells in the vagus trunk and ganglion cells in the intramural plexuses. The nerve fibers and cells in the oesophageal wall are pointed out by R.REMARK (1928).[131] R.GREVING (1931a)[43] described that the efferent nerve fibers arised from the autonomic center of the medulla oblongatae ends in the ganglion cells of the intermuscular plexus. The ganglion cells of the intermuscular plexus are sometimes gathered in a limited portion of the relatively large ganglion, and such grouped nerve cells have the characteristic of the sympathetic nervous system according to T.NISHIKAWA (1954),[116] M.EGUCHI (1954),[27] M.SATO (1956),[139] etc.. H.KIMATA et al. (1962)[76] described that the ganglion cells of " nuclear positive type " of the monoamine oxidase (MAO) activity were characteristic of the sympathetic nervous system. On the other hand, P.E.SMITH et al. (1940)[148] described that the parasympathetic preganglionic fibers of the vagus end in the ganglion cells of the intermuscular plexus of alimentary canals. The presence of the parasympathetic nerve fiber in the oesophagus also is elucidated by the description of T.KURE (1931)[91] and S.OKINAKA et T.NISHIMOTO (1951).[23] Accrodingly, it is clear that the ganglion cells in the intramural plexus are the significant nerve elements intercalated between the preganglionic and postganglionic fibers in the autonomic nervous system, although it is not distinguishable between the sympathetic and parasympathetic systems histologically. Accroding to the descriptions of the researchers, it have been noted that the stimuli in the peripheral tissues are conducted through the terminal reticulum of the autonomic nervous system. S.KAWATA et M.OKANO (1961)[73] could not recognize the presence of the autonomic nerve termination in the oesophageal wall of cattle.

From old times, the neuron theory of J.N.LANGLEY (1885)[98] had been supported by many investigators, but this theory was denied in general since the publication of the work of Ph.STOEHR,jr. (1932),[150] K.A.REISER (1932),[130] etc.. Ph.STOEHR,jr. (1932)[150] described that the autonomic nerve forms a fine closed and reticulated structure (terminal reticulum), instead of terminating freely. It is evidently formed the terminal reticulum in the cross striated muscle of the cattle oesophagus. However, the certain nerve of very small diameter freely isolated from the autonomic nervous system exists only in the oesophageal striated muscle, as described by K.HARTING (1934)[48] and H.SETO (1940).[143] This fine nerve fiber have a characteristic of the sympathetic nerve. It is dealt with accessory nerve fiber which will be described later. Author, as a rule, supports the interpretations of Ph.STOEHR,jr. (1932)[150]

and K.A.REISER (1932)[130] from the reason that the cross striated muscle fibers of the cattle oesophagus are superintended by the close contact with the terminal reticulum of the autonomic nervous system. Especially, the terminal reticulum is developed in the crico-oesophageal muscle and muscular coat of the upper end of the tube. There are the special cell nuclei. Author supposes that the special nuclei corresponds to the nuclei of syncytium of B.J.LAWRENTJEW (1926),[99] the terminal cells of T.SADA (1942),[137] the intercalated cells of T.WADA (1958a)[165] and the interstitial cells of CAJAL by Ph.STOEHR,jr. (1932, '49),[150][152] R.HONJIN (1951)[55] and T.NAKAMURA (1960)[113] respectively. The terminal reticulum of the autonomic nervous system is recognized in the ocular striated muscles of cat and human being by J.BOEKE (1909, '27)[10][11] and N.HIRANO (1940),[54] and in the lingual striated muscle of the human being by H.KUMAGAWA (1941)[86] respectively. The findings are well resembles to the fine reticulated structure in the cattle oesophagus. Moreover, T.SHIBA (1928)[145] and T.KURE (1931)[91] described that the ordinary moter end plate in the oesophageal striated muscle have the characteristic of the parasympathetic nerve, since the smaller accessory end plate has a characteristic of the sympathetic nerve. They also said that the medullated nerve fibers of 3 micron or less in the oesophageal muscle have the characteristic of the parasympathetic nerve. However, it is not one of the autonomic nervous system, because it has the myelin sheaths. Author will not agree with their interpretation.

Thus, it was proved the presence of the involuntary movement (automatism) in the cross striated muscle of the cattle oesophagus by the confirmation of the terminal reticulum of autonomic nervous system. It signifies that the muscularis of cattle oesophagus has the peculiarity as the visceral striated muscle differed from the skeletal muscles. S.KIN (1937)[77] reported the presence of the automatism in the oesophageal striated muscle of cat and rabbit.

c) Sensory innervation

T.KURE et al. (1949)[94] advocated the existence of the autonomic (sympathetic) sensibility. However, since the discovery of the typical sensory nerve termination by K.HARTING (1934),[48] etc., the autonomous sensoru-conduction theory is not supported generally. In the oesophageal wall of the cattle, the sensory nerve fibers are expressed as the thick medullated fibers. The confirmation of the sensory nerve fiber should be performed by observing its terminal apparatus. There was detected the intraganglionic, free and palisade-like nerve terminations and MEISSNER's corpuscle.

The presence of the intraganglionic nerve termination in the intermuscular plexus is recognized in the human oesophagus by T.SADA (1942),[137] in the oesophagus of the dog by A.OTSU (1953),[125] N.TANAKA (1953)[154] and G.SUGAMATA (1955)[153] and in the monkey's oesophagus by T.YAMAMOTO (1959)[176] respectively. The intraganglionic multi-branched sensory termination of the human being described by T.SADA (1942)[137] is developed more than in the oesophagus of the dog and monkey. They described that the intraganglionic sensory terminations would presumably originated from the afferent or sensory fibers derived from the vagus nerve. Author supposes that these appearances of nerve termination in the cattle oesophagus would show the apparatus of the sensory nerve termination described by T.SADA (1942),[137] A.OTSU (1953),[125] N.TANAKA (1953),[154] G.SUGAMATA (1955)[153] and T.YAMAMOTO (1959),[176] because that there could be detected the clear continuance of nerve fiber between the intraganglionic nerve termination and the intrinsic nerve fiber. However, the running and characteristic of the intraganglionic nerve termination is resembled to the findings of the previous researchers. This is differed from the pericellular termination (apparatus) which ends around the nerve cell bodies in the ganglia of the alimentary tracts described by C.ARNSTEIN (1895),[2] G.C.HUBER (1896),[59] C.GEGENBAUR (1903),[42] B.J.LAWRENTJEW (1929),[102] R.GREVING (1931a),[43] G.OTTAVIANI (1938),[126] R.HONJIN (1951)[55] and T.NAKAMURA (1960).[113] H.KIMATA et al. (1962)[96] described that the intraganglionic cells of the monoamine oxidase activity in the intermuscular plexus may have an intrinsic relationship with the receptors in the oesophagus, although it was not determined, which they belong to the afferent or efferent feature of the receptors. However, the intraganglionic nerve termination also can be clearly discriminated from the receptors due to its histological findings.

The free nerve termination was found commonly at the upper portion of the neck of the tube. H.SETO (1949)[143] described that the sensory nerve fiber in the visceral organ is principally the free termination, and its peripheral structure resembles that of the somatic sensory nerve fiber neuro-histologically. The free nerve termination in the skeletal muscles have been described by C.S.SHERINGTON (1894),[144] Ph. STOEHR (1922),[149] J.C.HINSEY (1927),[53] W.FEINDEL et al. (1948)[32] and I.NOJIRI (1963).[118] In the muscular coat of the oesophagus, the existence of the free nerve termination have been denied by T.SADA (1942)[137] and G.SUGAMATA (1955).[153] M.YAMAMOTO (1960)[177] described the branched sensory termination having some special cell nuclei between the muscle bundles of the muscularis of oesophagus of the formosan monkey. M.POBERAI et al. (1963)[128] detected the simple branched nerve termination in the smooth muscular coat of the inferior oesophagus of mouse. T.SATO (1949)[138] found the rather expanded simple branched nerve termination having the SCHWANN's nuclei in an inner muscular layer of the human stomach. In the cattle oesophagus such branched sensory termination were never detected.

The palisade-like nerve termination in the end of striated muscle fiber was found by the predecessors. This is evidently differed from the muscle spindle. That is, F.CREVATIN (1902)[21] named the nerve terminal apparatus in the ocular muscles of the camel " terminaison en capuchons ". A.S.DOGIEL (1906)[23] studied the same receptors in the ocular muscles of the human being and the other mammals. He said that this apparatus is located in the ends of the muscle fibers arranged like palisade, and the nerve fiber without the myelin sheath winds around the muscle fiber. G.H.SABUSSOW et al. (1964)[136] described the similar findings in the ocular muscles of the dog, frog, tortoise and the others. They said that there are many oval or ellipsoid nuclei (glia-like cell elements) called " protoplasmmass ". The palisade-like nerve termination in the oesophageal muscle of the cattle closely resembles the apparatus in the ocular muscles, therefore, it may be rather called " terminaison en capuchons " from its features. Such termination have a sensible function as well as it of muscle spindle.

The so-called corpuscle of MEISSNER is an interesting termination found in the oesophageal muscle of cattle. In literature, the presence of termination resembling to the so-called corpuscle of MEISSNER has been reported only in the human stapedius muscle by I.NOJIRI (1963)[118] that it resembles somewhat the corpuscle of MEISSNER. R.GREVING (1913a)[43] described the presence of MEISSNER's corpuscle in the submucous tissue of the cat oesophagus which will be described later. Author thinks that the corpuscle in cattle would be corresponded with MEISSNER's corpuscle described by Ph.STOEHR (1922)[149] and M.ISHIZAWA (1952),[62] from the reason that they resembles well each other in their feature. The corpuscle of 250 x 50 micron in cattle is by far larger than the nature that the size of MEISSNER's corpuscle is 100 x 40 micron according to Ph.STOEHR (1922)[149] and 100 x 45 micron owing to I.NOJIRI (1963).[118]

Although the involve termination and muscle spindle could not be confirmed clearly in the oesophageal muscle of the cattle, author will consider them for discussion of the proprioception in the muscularis of cattle oesophagus. The involve-like termination was sometimes found between muscle fibers, but it has not the complete natures. The involve termination have been detected in the muscular coat of oesophagus of the human being, dog and the others by K.HARTING (1934),[48] T.SADA (1942)[137] and N.TANAKA (1953).[154] However, A.OTSU (1953),[125] G.SUGAMATA (1955),[153] S.KAWATA et al. (1961)[72] and S.KAWATA et al. (1962a)[73] could not find any analogous termination in the muscular coat of the oesophagus of the horse, cattle, goat and dog. Moreover, the muscle spindle is generally classified into two kinds of the monomuscule fibroid and multimuscle fibroid according to the descriptions of D.K. Von BRZEZINSKI (1963)[163] and H.VOSS (1963).[164] Ph.STOEHR (1922),[149] J. BOEKE (1927)[11] and R.GREVING (1931a)[43] described the presence of the simple muscle spindles in the muscularis of the oesophagus, pharynx, larynx and eye-ball of cat and human being. The pressure sensitive mechanism of the muscle spindle have been discussed by D.JINNAI et al. (1958)[68] and C.BRIDGMAN et E.ELDRED (1963).[15] They noted that it is an afferent terminal apparatus which relates with the proprioception of the muscle. H.HOSOKAWA (1960)[58] described that the muscle spindle distributes abundantly in the coarse-acting skeletal muscles, but it is few in the visceral striated muscle of the supplying areas with the nerve of central nervous system. Accordingly, it is understandable that the muscle spindle is a very rare terminal apparatus in the muscularis of oesophagus, and attention will be drawn to the presence of any other terminations which should be regarded as sensory. The proprioception of the oesophageal wall should be considered, owing to the comprehensive findings. Author thinks that the findings of the " terminaison en capuchons " and MEISSNER's corpuscle in the oesophageal muscle of the cattle are mostly resembled to that of the ocular and ear-ossicle muscles, considering the peculiarity of the sensory function. S.KAWATA et M.OKANO (1961, '62a)[73)74)] found no such specialized sensory terminations in the oesophageal muscle of various animals included the cattle.

In the submucous tissue the sensory nerve termination was not found. T.YAMAMOTO (1959)[176)] described the various sensory nerve terminations in the submucous tissue of the oesophagus of the formosan monkey. T.SATO (1949)[138)] recognized the glomerular nerve terminations issued from the vagus in the submucous tissue of the human stomach. J.R.SETELO (1954)[142)] described the afferent nerve fiber accompanied by the vagus trunk in the colon and rectus of the human being. R.GREVING (1931a)[43)] described the presence of the MEISSNER's and the typical VATER-PACINI's corpuscles in the submucous tissue of the cat oesophagus. Such corpuscles were not detected in the submucous tissue of cattle oesophagus.

The nerve in the mucous membrane is poorly supplied, but a little sensory nerve terminations were found in the lamina propria of the cattle. G.RETZIUS (1892)[132] described the multiple and branched nerve terminations in the human oesophagus, while T.SADA (1942)[137] found no sensory nerve termination in the oesophagus of the man. T.YAMAMOTO (1959)[176] described the various serpentine fibers of the sensory nerve found in the lamina propria of the formosan monkey's oesophagus. A.OTSU (1953)[125] and N.TANAKA (1953)[154] recognized the various nerve termination in the mucous membrane of the oesophagus and the other alimentary canals of the dog and human being. In the lamina propria of the inferior oesophagus and cardiac part of the dog, the non-branched and simple branched nerve terminations have been described by G.SUGAMATA (1955)[153]. More particularly, the sensory nerve fiber was never detected by S.KAWATA et al. (1961)[73] and S.KAWATA et al. (1962a)[74] in the oesophagus of the horse, cattle, goat and dog. In the cattle oesophagus the sensory nerve termination was found hardly in the middle and lower portions of the neck. In the lamina propria of the rabbit oesophagus, the involve nerve termination have been noted by K.HARTING (1934)[48] in detail. Some of the nerve fibers in the lamina propria of the cattle oesophagus enters into the papillae of connective tissue. S.KAWATA et al. (1962a)[74] detected some nerve fibers in the papillae of lamina propria of the dog, but never found it in the horse, cattle and goat.

As known from the findings above, the intraepithelial nerve fiber in the cattle oesophagus was a simple non-branched nerve termination. Its peripheral structure is simpler than that of the nerve fibers in the epithelium of the oesophagus of the domestic animals and human being described by Ph.STOEHR (1922),[149] H.SETO (1949),[143] A.OTSU (1953),[125] N.TANAKA (1953)[154] and O.KROELLING et H.GRAU (1960).[82] G.RETZIUS (1892),[32] using the chrome silver method, demonstrated the nerve entering in the epithelium of the cat oesophagus. He said that the nerves in the oesophageal mucous membrane did not develop so numerous as in that of the pharynx and larynx and they are located much closely to the basement membrane. L.M.De WITT (1900)[22] described that many of the terminal fibers ended on the deeper cells of the epithelial layer cuold be traced in the dog, cat and rabbit. S.KAWATA et al. (1962a)[74] detected the intraepithelial nerve fibers in the oesophagus of the dog. These nerve terminations should be considered as the afferent fibers, as described by H.SETO (1940)[143] and M.ISHIZAWA (1951).[61] G.KAWAHARA (1950)[71] found the fine intraepithelial nerve fiber in the apical portion of the horse tongue. W.ELLENBERGER (1911),[28] R.E. HABEL (1956)[46] and K.J.HILL (1957)[51] found the pretty fine nerve fibers in the mucous epithelium of the ruminant forestomach, and R.E. HABEL (1956)[46] pointed out that these nerve fibers may be sensitive to pressure or tention. The existence of the intraepithelial nerve termination in the other alimentary tracts of the various mammals have been mentioned by many researchers. However, the distribution of the intraepithelial nerve fiber was not found by N.P.SABUSSOW (1913),[135] T.SADA (1942),[137] G.SUGAMATA (1955),[153] S.KAWATA et al. (1961)[73] and S.KAWATA et al. (1962a)[74] in the oesophagus of the human being, horse, cattle, goat, cat and rabbit. T.YAMAMOTO (1960)[177] could not find the intraepithelial nerve fiber in the oesophagus of the formosan monkey.

Thus, the sensory nerve terminations were commonly found in the vestible and upper end of the cattle oesophagus, the junction of the pharynx and oesophagus. These specialized sensory terminations, besides proprioception of the wall, function as the receptors which conduct the impulse towards the centrum for the food-intake and peristalsis in the oesophagus. According to W.W.TUTTLE et B.A.SCHOTTELLIUS (1961),[160] the mechanical stimulation of the sensory nerve terminations in the pharynx and oesophagus activates the swallowing center in the medulla oblongatae.

d) Moter innervation

The muscular coat of the oesophagus is the most important lamina for intake of food, while it functions as the motive power for rumination of food or vomiting of gass from the rumino-reticulum of the cattle. From the features of the nerve supply, it is considered that there is a delicate movement function and regulation in the muscular coat of the cattle oesophagus.

The terminal nerve bundles divided from the intramuscular network are passed over some muscle fibers to the moter terminal apparatus. Namely, they runs for very short distance before terminating on the moter end plate. W.FEINDEL, J.R.HINSHAW et G.WEDDELL (1952)[33] described that in the mammalian striated muscle there distributes the so-called isolated nerve fiber which reach by far isolate portions after dividing from the intramuscular network. Although such nerve fiber was rarely found in the oesophageal muscle of cattle, the terminal minute fibers passes usually over the muscle fibers of 2 to 3 or more before reaching each moter end plates. Each moter (neuro-muscular) unit of the muscularis of cattle oesophagus, as estimated above, has 10 to 30 muscle fibers. In literature, the moter unit of the various striated muscles has been described by many researchers. P.TERGAST (1873)[157] estimated that the moter unit of the sheep extra-ocular muscles has 3 to 10 muscle fibers in number. E.BORS (1926)[13] estimated 5 to 6 for the extra-ocular muscles, and about 50 for the semitendinous in the human being. T.FUKUSHIMA (1927, '28)[39][40] estimated about 5 to 10 or more for the longissimus dorsi, psoas majo and gracillis muscles of the horse, cattle, dog, rabbit and the others. A.Van HARREVELD (1947)[161] reported 100 to 125 muscle fibers per one moter unit in the gastrocnemius of the rabbit. P.A.BERLENDIS et L.G.De CARO (1955)[5] estimated 27 in the stapedius and 30 in the tensor tympani muscle of the rabbit. B.FEINSTEIN et al. (1955)[34] estimated 9 muscle fibers per one moter unit in the lateral rectus ocular muscle, 25 in the platysma, 108 in the first digit lumbrical and 2,000 in the medial head of gastrocnemius of the human being. T.MALMFORS et J.WERSAELL (1960)[103] found each moter unit contained between 14 to 20 muscle fibers in the stapedius of rabbit. S.G.KULKIN (1963)[85] described that the moter unit of the rabbit diaphragm has 12 to 20 muscle fibers. C.E.BLEVINS (1964)[7] described that the number of stapedius muscle fibers per one moter unit in the cat is probably 3 or less, and it is only one to 2 less than that of the tensor tympani of cat reported in 1963. More particularly, L.RUEDI (1958)[134] estimated 2 to 3 muscle fibers per one moter unit in the human laryngeal muscles. C.R.DUTTA et J.V.BASMAJIAN (1960)[26] reported 2 to 4 muscle fibers per one moter unit in the superior and middle pharyngeal constrictors and 4 to 6 in the inferior pharyngeal constrictor.

According to C.R.DUTTA et J.V.BASMAJIAN (1960),[26] the control of contraction of the muscle tissue depends on the smallness of the moter unit within the muscle. That is, generally, it can be thought that the muscles performing the delicate movement and regulation have the smaller number of muscle fibers per one moter unit. On the other hand, the large strong-acting muscles have the larger moter units. Although the value is little differed from each other by the researchers, whereas it is difficult to estimate the size of one moter unit and in general, the moter unit of the oesophageal muscle of the cattle is a little larger than that of the extra-ocular, pharyngeal and laryngeal muscles, and it is by far smaller than that of the skeletal muscles. It mostly resembles that of the striated muscles attached to the ossicles of the ear (P.A.BERLENDIS et al., 1955[5]) and T.MALMFORS et al., 1960[103]), platysma (B.FEINSTEIN et al., 1955[34]) and diapgragm (S.G.KULKIN, 1963[85]). From such interesting anatomical corollary, it is knowable that the oesophageal muscle of the cattle had the delicate function and may be considered to be of intermediate type in between both categories of muscle mentioned above.

In the crico-oesophageal muscle of the cattle, it has the smallest number of muscle fibers per one moter unit. This coincides with that of the muscles attached to the eye-ball (E.BORS, 1926[13]), the pharynx (C.R.DUTTA et al., 1960[26]) and the larynx (L.RUEDI, 1958[134]). Author thinks that the crico-oesophageal muscle of the cattle forms the sphincter with the circular muscle at the upper end of the tube, therefore, it have a pharyngeal constrictor-like characteristic rather than the proper oesophageal muscle, considering the neuro-muscular unit mentioned above.

The moter end plate was classified into two types I and II. The the type I has the ordinary features of the moter end plate in the skeletal muscle fibers. T.SHIBA (1928)[145] and T.KURE et S.OKINAKA (1956)[95] described that the moter end plates exists on the obscure portion of the cross striated structure of the muscle fibers. The histological findings of moter end plates in the striated muscles have been described by L.BREMER (1882),[14] E.FISCHER (1887),[35] W.KUEHNE (1887),[84] Ph.STOEHR (1922),[149] I.IWANAGA et O.KIMURA (1923),[65] C.Ry.CAJAL

(1925),[18] K.NAKAMOTO et N.KURA (1926),[112] J.BOEKE (1909, '27, '28),[10)11)12] T.FUKUSHIMA (1927, '28),[39)40] B.J.LAWRENTJEW (1928a and b),[100)101] K.MONDEN (1939),[110] N.HIRANO (1940),[54] T.KUMAGAWA (1941),[88] L.W.JARCHO et al. (1952),[67] W.FEINDEL et al. (1952),[33] W.V.COLE (1955),[20] M.KOBAYASHI (1956),[81] H.G.SCHWARZACHER (1957),[141] H.J.GURKOW et T.H.BAST (1958),[45] T.TANAKA (1958, '59),[155)156] A.A.MAXIMOW et W.BLOOM (1958),[107] K.NOZAKI (1959),[120] T.NARA (1961),[115] S.KAWATA et al. (1962a)[74] and P.G.MARCHISIO (1964).[104] The histological feature of the type I end plate in the oesophageal muscle of the cattle resemble mostly those in the oesophagus of the various mammals described by L.M.De WITT (1900),[22] B.J.LAWRENTJEW (1929),[102] R.GREVING (1931a),[43] G.OTTAVIANI (1938),[126] T.SADA (1942),[137] Ph.STOEHR,jr. (1949)[152] and S.KAWATA et M.OKANO (1961),[73] although there are some incidental components in the moter end plate. In the ordinary moter end plate of the cattle oesophagus, the number of terminal cells corresponds with that in the moter end plate of the ocular and ear-ossicle muscles described by I.IWANAGA et O.KIMURA (1923),[65] N.OHTA (1958)[122] and I.NOJIRI (1963).[118] In the skeletal muscles the moter end plate is generally larger than those of the ocular and oesophageal striated muscles, as known by the descriptions of many other researchers.

E.AGDUHR (1916)[1] and A.HESS (1963)[50] reported the multiple innervation which forms two moter end plates on a striated muscle fiber. The multiple (double) innervation in the muscularis of cattle oesophagus was found in common and controlled with the unitary nerve fiber.

According to N.OHTA (1958),[122] the multiple innervation can be observed often in the ossicle muscles of ear of the cat, but the moter end plates are innervated by the distinct two nerve fibers, the dual innervation. I.NOJIRI (1963)[118] detected the some multiple innervations controlled by a unitary nerve fiber in the human stapedius muscle. C.E.BLEVINS (1963)[6] recognized the multiple innervation being controlled by a single axon in the tensor tympani muscle of the cat, but he, in 1964, detected no the multiple end plates on a single muscle fiber in the stapedius muscle of the cat. Also, the multiple end plates have been seen in a few muscle fibers of the tensor tympani of the cat by S.D. ERULKAR et al. (1964).[30] However, there is not counted the number of nerve fiber entering into the multiple innervation.

The thin nerve fiber in Figs. 41, 42, 44, 72, 73 and 75 have been found by L.BREMER (1882)[14] as accessory fiber in the frog's skeletal muscle and by J.BOEKE (1909)[10] as secondary fiber in the human ocular muscles respectively. The reports of the researchers have each difference in their interpretation of the accessory nerve fiber in the moter end plate. S.Ry.CAJAL (1925),[18] N.HIRANO (1940),[54] H.KUMAGAWA (1941)[86] and the others described that the accessory nerve fiber is derived from the ordinary thick nerve fiber of the lingual and extra-ocular muscles of the human being and the others. Ph.STOEHR (1922)[149] described the presence of the sympathetic sccessory nerve fiber in the moter end plate, but he, in 1949, noted that the accessory nerve fiber has no characteristic of the sympathetic nerve, and criticized the opinion of J.BOEKE (1909).[10] T.SADA (1942)[137] also described that the accessory nerve fiber can be determined to be neither the autonomic nerve nor the sympathetic nerve, but it is a branch derived from the thick moter nerve fiber. T.TANAKA (1958, '59)[155) 156)] denied the presence of the accessory (non-medullated) moter nerve fiber being terminated in the sole plate of the vocal muscles of the cat. On the other hand, J.BOEKE(1909, '27)[10) 11)] described that the accessory nerve fiber is a branch derived from the sympathetic nerve. I.IWANAGA et O.KIMURA (1923),[65] K.NAKAMOTO et N.KURA (1926),[112] N.KURA (1927),[89] B.J.LAWRENTJEW (1928a and b)[100) 101)] and G.OTTAVIANI (1937)[126] supported the opinions of J.BOEKE (1909).[10] S.G.KULKIN (1963)[85] reported the presence of the sympathetic accessory fiber in the moter end plate of the tortoise's diaphragm. K.HARTING (1934)[48] and H.SETO (1940)[143] described that the terminal fiber freed from the autonomic nervous system exists only in the striated muscle of the human oesophagus. As mentioned above, author supposes that the accessory nerve fiber in the oesophageal muscle of the cattle will have the characteristic of the sympathetic nerve from the reason that it always is thinner than the main or ordinary nerve fiber and related to the development of the terminal reticulum of the autonomic nervous system. Namely, author would like to support the opinions of J.BOEKE (1909, '27),[10) 11)] I.IWANAGA et al. (1927),[65] K.NAKAMOTO et N.KURA (1926),[112] N.KURA (1927),[89] K.HARTING (1934),[48]

G.OTTAVIANI (1937),[126] H.SETO (1940),[143] H.KUMAGAWA (1941)[86] and S.G. KULKIN (1963).[87] Moreover, the accessory nerve fiber does not anastomose with the terminal axons in the end plate of ordinary moter nerve fiber, as described by many previous researchers. J.BOEKE (1909),[10] I.IWANAGA et O.KIMURA (1923),[65] T.SHIBA (1928),[145] T.KURE (1931),[91] Y.KATO (1951)[69] and M.ISHIZAWA (1952)[62] described that the accessory nerve fiber is concerned with the tonus and nutrition of the muscle. T.ISSIKI (1928)[63] and T.KURE et al. (1939)[92] described that the striated muscle of the dog oesophagus is nourished by the sympathetic and parasympathetic nerves.

The presence of the periterminal network in the ordinary moter end plates have been recognized by J.BOEKE (1909),[10] E.AGDUHR (1916),[1] J.W.LAGELAAN (1922),[97] I.IWANAGA et O.KIMURA (1923),[65] S.Ry.CAJAL (1925),[18] B.J.LAWRENTJEW (1928a and b),[100][101] G.OTTAVIANI (1938),[126] T.TANAKA (1959),[156] S.KAWATA et al. (1962b),[74] while it was denied by S.S.TOWER (1931)[158] and T.SADA (1942).[137] H.J.WIKINSON (1930),[173] A.A.MAXIMOW et W.BLOOD (1958)[107] and I.NOJIRI (1963)[118] described that it is an artificial product. Author, as a rule, support the opinion of H.J.WIKINSON (1930)[173] and the others, from reason that it was rarely observed in the sections of silver super-impregnation.

In the oesophageal muscle of the cattle, both the ultraterminal nerve fiber and the " terminaison en grappe " are found rarely. The former is a thin branch furcated from the main nerve fiber of the moter end plate. J.BOEKE (1909, '27)[10][11] mentioned that it is a component in the ordinary moter end plate. I.IWANAGA et O.KIMURA (1923)[65] described that the ultraterminal nerve fiber exist very rarely only in 23 per thousands of end plates in the ocular muscle of the human being. T.FUKUSHIMA (1928)[40] denied the presence of the ultraterminal nerve fiber in the longissimus dorsi, psoas major and gracillis muscles of the horse, cattle, dog, rabbit and the others. The presence of the ultraterminal nerve fiber may be a characteristic as so-called visceral striated muscle. The " terminaison en grappe " have been described by J.BOEKE (1927)[11] in the ocular muscle of the cat and by B.J.LAWRENTJEW (1928a)[100] in the laingual muscle of the frog respectively. T.SADA (1942)[39] described that the moter end plate of the human oesophagus is " terminaison en grappe " in general, but it was rare in the cattle oesophagus.

The type II moter end apparatus really resembles the moter termination described by C.B.DUTTA et J.V.BASMAJIAN (1960)[26] in the pharyngeal constrictors of the rabbit. The moter termination somewhat resembling to the type II end apparatus of the cattle has been described by D.W. BURNASCHOWA (1963)[17] in the rectal ocular muscle of the reptiles. It is called the so-called " bajonettartige Apparate ", and the terminal fibers furcates from a moter nerve fiber supplies on about 4 muscle fibers. There is seen the plasmatic component of SCHWANN's nuclei in the terminal apparatus. The nucleus-plasmodium was not found in the type II end apparatus of the cattle. L.F.MAWRINSKAJA (1952)[106] described that in a comparative study on the moter terminations of the skeletal muscles of vertebrates, it is the specific apparatus dislocated from the phylogeny of moter nerve termination and typical apparatus always exists in the tortoise's skeletal muscles. In the crico-oesophageal muscle this apparatus is accompanied by an accessory nerve fiber. C.R.DUTTA et J.V.BASMAJIAN (1960)[26] did not recognize the autonomic or sympathetic innervation in the pharyngeal constrictors of the rabbit. L.F.MAWRINSKAJA (1952)[106] and D.W.BURNASCHOWA (1963)[17] also described no the distribution of the fiber of autonomic nervous system.

From the findings of the moter end plates, it is considered that the striated muscle of the cattle oesophagus is innervated by the cranial moter nerve fibers from the centrum through the vagus. The distribution of the cranial moter nerve fibers was elucidated by the analytic study of the fiber construction of the supplying nerves, as mentioned above. In literature, T.SHIBA (1928),[145] T.KURE et al. (1929),[90] T.KURE et al. (1939),[92] T.KURE et S.OKINAKA (1949, '56)[94][95] described that the striated muscle of the oesophagus is innervated by the autonomic nerve, instead of the cranial moter nerve fibers. Such opinions have been mostly supported by H.KIMATA et al. (1962).[76] They have advocated that the striated muscle of the oesophagus have an automatism by the distribution of the autonomic nerve. The distribution of the autonomic nerve in the goat oesophagus have been studied by S.YAMADA et al. (1962),[174] H.KIMATA et al. (1962)[76] and S.YAMADA et al. (1964)[175] histochemically. On the other hand, L.M.De WITT (1900),[22] S.W.RANSON et P.R.BILLINGSLEY

(1918)[129], T.SADA (1942)[137], S.FUKUYO (1943)[41], S.KAWATA et al. (1961)[73] and S.KAWATA et al. (1962a)[74] described that the efferent medullated nerve fibers in the vagus supply the striated muscle of the oesophagus. S.KIN (1937)[77] described that the striated muscle of the oesophagus is controlled by the cranial moter fibers derived from the vagus nerve. He also noted that the contraction of the oesophageal muscle is functioned tonically by the sympathetic nerve, and suppressively by the parasympathetic nerve. G.C.KNIGHT (1934)[80] also described that the oesophageal striated muscle is motivated more powerfully by the vagus and sympathetic nerves.

Author supposes that the moter end plates of the oesophageal muscle of cattle are supplied mainly by nerve fibers of 2 to 4 or more micron in diameter, as mentioned above. This morphology is similar to thickness of supplying nerve fibers in the other skeletal muscles described by the other researchers mentioned above. From these results, author considers that the contraction of the proper muscularis of cattle oesophagus will be caused through the moter nerve fibers running out from the vagus. If the swallowing center of the medulla oblongatae was stimulated through the sensory nerve in the peripheral tissue, the moter nerve fiber in the central nervous system is excited following by the action potential of the muscle. This action potential is propagated to the moter end plates. In addition, the proper muscularis is toned by the fibers of autonomic nervous system. Namely, it is toned by the sympathetic accessory nerve fiber for the more strong contraction of the muscular coat, while by the parasympathetic nerve for the more strong inhibition of the muscle motion.

From the findings of respective nerve terminations mentioned above, author think that the muscularis of cattle oesophagus should be treated as so-called visceral striated muscle, whereas there are many features differed from the muscles of torso and limbs. Author describe especially that in a wide significance the so-called visceral striated muscle is definitely differed from the pure skeletal muscle anatomically, neuro-histologically and functionally.

e) Innervation of the oesophageal gland

The nerve of the oesophageal gland is developed in the vestible in the cattle as well as the other animals. (H.WAKURI et al., 1963a)[170] The rough nerve network formed around the glandural duct is corresponded to the periductal plexus of T.WADA (1958a)[165] and T.NAKAMURA (1960).[113] Author found the sensory nerve fibers richly innervating around the duct and the cells of terminal portion of the oesophageal gland of the cattle. L.M.De WITT (1900)[22] found the sensory nerve fiber in the duct of oesophageal gland of the dog, cat and rabbit. T.SADA (1942)[137] described the sensory nerve fiber ending freely in the connective tissue around the duct and the intraductal branched nerve fiber in the oesophageal gland of the human being. N.TANAKA (1953)[158] reported the presence of the efferent medullated fibers entered into the oesophageal gland of the dog. Similar finding have been described by S.KAWATA et al. (1962a)[74] in the oesophageal gland of the dog. H.KUMAGAWA (1941)[86] found the thick medullated sensory fiber in the duct wall of the anterior lingual gland of the human being. The sensory nerve fiber was not found between gland cells of the terminal portions of oesophageal gland of the cattle, as description of L.M.De WITT (1900)[22] and T.SADA (1942)[137]. The sensory nerve fiber functions the secretion of gland.

3. NERVE SUPPLY IN THE OESOPHAGEAL PAPILLA

The distribution of the nerve fibers in the oesophageal papilla is poor. In literature, the nerve fiber in the palilla-like organ (mechanical papilla), morphologically resembling the oesophageal papilla, is poor in general. T.YAMAMOTO (1959)[176] described the simple non-branched or branched nerve termination in the lamina propria of small conical papillae at the soft palatine of the formosan monkey. He also found rarely the intraepithelial nerve fiber. K.KUBOTA et al. (1963)[83] described that the nerve fibers in the fungiform and filiform papillae of the marsupials are terminated directly and sharply beneath the mucous epithelium. Such findings mostly resembles those of the oesophageal papilla of the cattle.

On the neccessity for oesophageal papilla, author thinks that this organ protruded from the surface of the mucous membrane could every time receive even a little stimuli, because of the mucous membrane always expanding by the swallowing and rumination. However, considering the macroscopical and histological features of the oesophageal papilla, author guesses that it is an organ belonged to the category of so-called mechanical papilla in the mouth, tongue, forestomach and the others.

Thus, by the discussion above, author proved neuro-histologically that there are distributed triply the autonomic, sensory and moter nerve terminations in the oesophageal wall of cattle. In consequence, author thinks that the movement of oesophagus is an associated function developed by the interaction of the various nerves supplying in every laminae of tube, as described by S.OKINAKA (1952).[124]

V. SUMMARY

For the purpose to know the morphological peculiarities of the nerve supply of the cattle oesophagus, the systematic observations of the innervation of the wall of upper half portion of tube and the oesophageal papilla have been carried out anatomically and neuro-histologically. For the present investigation, 29 specimens were used as a total. Histological specimens cut out from 24 cases were fixed with 10 per cent neutral formol solution or 95 per cent alcohol, and mounted in paraffin. Sections were treated with BODIAN's silver protargol impregnation, Type II silver impregnation of CAJAL and FLETCHER's myelin technique, and some sections were stained with the

hematoxylin and eosin and one per cent solution of aniline blue.

The principal results obtained in present research are summarized as follows.

1. Macroscopically, the upper half portion of the oesophagus is innervated by the pharyngeal branch, superior laryngeal nerve and recurrent nerve issuing from the vagus mainly. There also are the sympathetic nerve derived from the superior and inferior cervical ganglia supplied. The lateral laryngeal nerve is not innervated in the tube.

2. In the cervical portion there is the vago-sympathetic trunk formed, whereas the vagus nerve unites with the sympathetic nerve. Histilogically, the vagus and sympathetic nerves are covered with the different connective tissue sheaths. The vagus evidently includes the medullated and non-medullated nerve fibers of the various thickness and the nerve cells of the unipolar, pseudo-unipolar or multipolar form. The nerve cells have the nucleoli of 1 to 2 in number.

3. The recurrent nerve shows the two peaks of the fiber-thickness, 2 to 4,9 micron for 47 per cent and 6 to 7,9 micron for 27,5 per cent in the preparations of FLETCHER's myelin technique. The intermuscular and intramuscular nerve branches has the two peaks of 2 to 3,9 micron for 44,5 per cent and 5 to 7,9 micron for 36,5 per cent in the former, and 2 to 3,9 micron for 57 per cent and 5 to 5,9 micron for 21 per cent in the latter respectively. It is likely that the small diameter

nerve fiber is the motoric, while the larger diameter nerve fiber is the sensory, supposing from the formation ratio of each nerve apparatus in the terminal portions. There also is the non-medullated nerve fibers distributed.

4. In the outer connective tissue sheath the rough nerve network is formed conspicuously at the upper end portion of the oesophagus, but it is unconspicuous in the middle and lower portions of the neck of the tube. The intramural plexus is formed within the muscular coat of the whole oesophagus and mainly at the upper end portion in the submucous tissue and lamina propria. Particularly, the triplicate intermuscular plexuses are formed between the crico-oesophageal muscle and the muscular coat of upper end of the tube. The ganglia were found at the node of the nerve trunks in the outer connective tissue sheath, intermuscular and submucous plexuses respectively. The ganglion cells are grouped in about 20 in the outer connective tissue sheath, about 5 to 25 in the intermuscular plexus and about 10 to 20 in the submucous plexus in the crossing section of the middle part of the rather large ganglion. In the intramural plexus the nerve cells are mostly multipolar and classified into the DOGIEL's types I and II in the adult, while young type in the young cases. Moreover, the intramural blood vessels are innervated by the nerve network (plexus) forming around the vessels.

5. There were detected clearly the distribution of the autonomic,

sensory and moter nerve terminations in the oesophageal wall of the cattle.

6. The cross striated muscle fibers and blood capillaries are superinted by the contact of the terminal reticulum (STOEHR) of the autonomic nervous system. The terminal reticulum is developed particularly in the crico-oesophageal muscle and the muscular coat of the upper end portion of the tube. There are the special cell nuclei which are little larger than SCHWANN's nuclei. In the cross striated muscle of the cattle oesophagus, the sympathetic nerve fiber is isolated freely from the autonomic nervous system, as accessory nerve fiber.

7. The sensory nerve terminations were discriminated into the free, " terminaison en capuchons ", corpuscle of MEISSNER and intra-ganglionic end apparatus in the muscular coat. It is distributed moderately in the upper end portion and rarely in the middle and lower portions of the neck of the tube. In the mucous membrane there is mainly the free terminal apparatus supplied. The sensory nerve fibers are existed around the terminal portions and ducts of the oesophageal gland.

8. The moter end apparatus is divided into two shapes : types I and II. The type I resembles principally the moter end plate (" en plaque ") in the skeletal muscles. It is measured 15 x 25 to 40 x 65 micron in range of dimension : 30 x 50 micron on an average.

After taking the myelin sheath off, the terminal axons arborizes into 3 to 4 and has the 6 to 9 grouped oval or ellipsoid nuclei : 8 on an average. The periterminal network was not observed in general. Usually, the moter end plate forms only one on one muscle fiber, but the multiple innervation controlled by an unitary nerve fiber is moderately found. The type I end plate is sometimes accompanied by the accessory nerve fiber in the whole portion of the upper half of the oesophagus. The accessory end plate is more simple in its structure than the main moter end plate. The " terminaison en grappe " and ultraterminal nerve fiber also was rarely found.

The type II moter end apparatus (bajonettartige Apparate) was found only in the crico-oesophageal muscle. There also found the accessory nerve fiber.

9. The moter unit in the oesophageal muscle of the cattle is consisted of about 10 to 30 muscle fibers. The crico-oesophageal muscle have about 4 or more muscle fibers per one moter unit.

10. The nerve distribution in the oesophageal papilla is rather scarce. The simple serpentine nerve fiber is poor in the lamina propria and moderate in the secondary papillae. There exists the special nerve cells around the blood vessels in the lamina propria.

VI. CONCLUSIONS

On the basis of the data obtained from the neuro-histological research, the remarkable properties of the oesophageal wall of cattle are to be concluded as follows.

1. The oesophageal wall is triply innervated by the each terminations of the autonomic, sensory and moter nerves derived from both the branches of vagus and the sympathetic nerve.

2. Particularly, it is clear that the proper muscularis of cattle oesophagus has the peculiarities as visceral striated muscle being differed from the muscles of torso and limbs, while the crico-oesophageal muscle has a characteristic as rather pharyngeal constrictor, from the findings of the neuro-muscular (moter) unit, various sensory and moter terminations.

3. No muscle spindle was found, but the proprioception of the oesophageal wall should be confirmed by the comprehensive findings of the specialized sensory terminations.

4. The nerve supply of the oesophageal papilla of cattle was researched.

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牛の食道の神経分布に関する解剖学的，組織学的研究

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和栗秀一

筆者は，反芻類（牛）の食道の機構とその特異性を解明する目的で，支配神経についての若干の系統解剖学的観察に加えて，神経組織学的な立場より詳細な検索を行なった。

支配神経の分布の観察には4例の個体が供試された。また組織学的検索には25例の食道が使用され，大部分は10%中性ホルマリン，一部は95%アルコールを以て固定され，パラフィン包埋ののち，15～20μの連続切片となした。神経要素の染色には，BODIAN氏鍍銀法，CAJAL氏後鍍銀法，FLETCHER氏髄鞘染色法を応用し，また必要に応じてH-E染色，また神経線

維と結合織線維との鑑別に1%アニリン青液が使用された。

検索によって得られた主な成績は次のように要約される。

1)、解剖学的に、牛の食道の上半部は迷走神経から分枝した咽頭枝、上喉頭神経および反回(下喉頭)神経によって支配されており、またこれら神経枝には交感神経要素が随伴している。外喉頭神経は食道には分布していない。

2)、迷走神経は、頸部では交感神経と連合して共通幹を形成しているが、組織学的に両者は別々の被膜で包被されている。迷走神経には種々の太さの有髄および無髄神経線維が含まれており、また神経の上頸部の高さに単極状、偽単極状あるいは多極状の神経細胞が多量に含まれている。神経細胞には1個、稀に2個の核小体が存在している。所見より、これら神経細胞は自律神経系にぞくするものと思われる。

3）．反回神経は食道の上半部の機能と密接な関連を持っているが，その線維構成は2～5μ（約47％）と6～8μ（約27.5％）に峰がみられる。なお，食道壁（筋層）における終末神経線維束の線維口径の分布をみると，2～4μ（約57％）と5～6μ（約21％）の二峰性曲線を示している。これらの数値は壁内とくに筋層における運動と知覚両神経終末の分布の量的様相とほゞ一致している。

4）．外膜における神経分布は，食道の上端部に粗大な神経網が著明に形成されているが，中および下頸部において網眼の形成は不明瞭である．壁内神経叢は筋間および粘膜下織に，また上端部（前庭部）の固有層において粘膜神経叢の形成が認められた。筋間神経叢は，とくに，食道上端と輪状食道筋の移行部辺りに三重に形成されているが，これは，食道のこの部位の運動と密接な関係を持つものと思われる。

神経節は外膜，筋間および粘膜下織の各神

経叢の神経線維束交叉部に存在しており，1個の神経節内の神経細胞数は，節のほゞ中央断面部において，外膜で約20個，筋間で5〜25個，下織では10〜20個である。これら神経細胞は大部分が多極性で，DOGIELのIおよびII型が区別され，若い個体においては幼若型が多い。なお，壁内血管の周囲には微細な神経網の形成がみられる。

5）．牛の食道壁内には，自律（植物）神経，知覚神経および運動神経の各終末の分布が認められた。

6）．自律神経性の終末装置は無髄線維の微細な網眼構造，つまりTerminal reticulum (STOEHR)で表され，食道横紋筋線維および付近の毛細血管，あるいは食道腺の導管は一部この終末網の接触によって主宰されている。自律神経性のTerminal reticulumは食道上端部において，とくに発達しており，そこにはSCHWANN氏核より若干大きい特殊細胞核の存在がみられる。なお，食道横紋筋には，自律神経系から遊離した

交感神経性の副線維（後述）の分布がみられる。

7）．知覚神経の終末は食道の上部に普通に検出され，中および下頸部には少ない。筋層における終末は蛇行性の不分岐自由終末のほかに，頭巾状終末，マイスネル小体，それに筋間神経節内の蛇行性の分岐自由終末などである。粘膜固有層および上皮においては，蛇行性の不分岐自由終末が主体で，また食道腺の終末部および導管においても知覚神経線維の分布が認められた。

8）．運動性終末は二通りの型（通常型と銃砲状終末）が分類された。通常の第I型終末の形態は骨格筋における終板に類似しており，食道全長に分布している。大きさは平均30×50μ（15×25μ～40×65μ）を計測し，終末軸索は髄鞘消失後，3～4本に分岐し，6～9個（平均8個）の卵円形あるいは楕円形の核が集団をなしている。終末周囲網（BOEKE）は認められない。一般に，第I型終板は

1本の筋線維上に1個形成されて，単純支配の特徴を示しているが，この他に1本の筋線維上に主終板と単純な副終板を同時に形成する，いわゆる重複支配が認められる。後者は単一神経元の支配を受けている。また第I型終板には，ときどき無髄神経線維が進入するが，これは前述したように，自律神経系から単離した副神経線維（BOEKE）に一致する。なお，稀に，ブドウ状終末と超終末神経線維の存在が発見された。

第II型の銃砲状終末は輪状食道筋において検出され，またこの終末には副神経線維の進入がみられる。

9)，牛の固有食道筋の運動（神経－筋）単位は10～30本の筋線維からなっており，輪状食道筋では4本前後の筋線維が単位となっている。

10)，食道乳頭の神経分布は量的には貧弱であるが，少数の蛇行神経線維の分布がみられ，二次乳頭には適度に進入し，尖鋭状に終

来している。また固有層の主として血管の周囲には特殊神経細胞の分布がみられた。

以上の所見より，牛の食道の固有性は次のように結論づけることができる。

A．牛の食道は，自律，知覚および運動の各神経終末によって三重の支配を受けている。

B．とくに，知覚終末，運動終末，神経－筋単位の大きさなどの所見から，固有食道筋はむしろ耳小骨筋に，また輪状食道筋は咽頭筋，喉頭筋あるいは眼筋にほゞ似た特徴をもっている。結局，牛の食道筋は体躯や四肢の骨格筋と違ういわゆる内臓横紋筋としての特性をもち，その運動は相当に鋭敏であることが知られる。

C．筋紡錘は検出されなかったが，明瞭なほかの知覚神経終末が発見されたので，固有知覚の存在は肯定される。

Explanation of Plate-Figures

PLATE I

Fig. 5. Cross section of the vago-sympathetic trunk. The thich trunk is vagus, and the sympathetic nerve is the thin trunk. Formol.-Fix. FLETCHER's Stain.

Fig. 6. Photomicrograph showing the medullated and non-medullated nerve fibers in the sagittal section of the vagus. Formol.-Fix. FLETCHER's Stain.

Fig. 7. Note the axons of various thickness in the cross section of the vagus. Formol.-Fix. BODIAN's Stain.

Fig. 8. Photomicrograph showing the nerve fibers in the sympathetic trunk. Formol.-Fix. FLETCHER's Stain.

Fig. 9. Nerve cells in the vagus trunk at the middle portion of the neck. Formol.-Fix. FLETCHER's Stain.

Fig. 10. The magnified vagal nerve cells. Formol.-Fix. BODIAN's Stain.

Fig. 11. Cross section of the recurrent nerve at the upper portion of the neck. Formol.-Fix. H-E Stain.

Fig. 12. Photomicrograph showing the medullated and non-medullated fibers in the recurrent nerve. Formol.-Fix. FLETCHER's Stain.

PLATE I

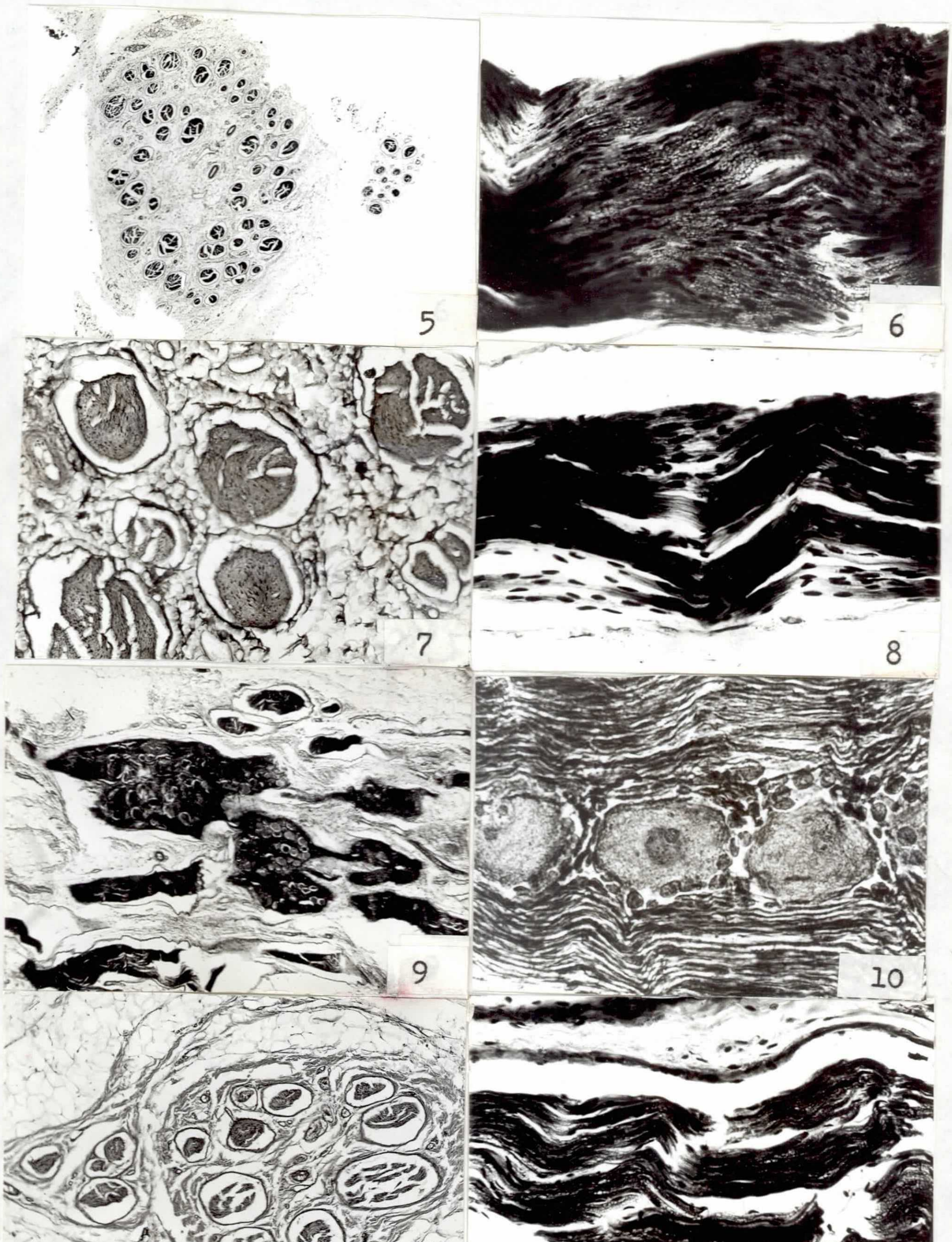


PLATE II

Fig. 13. Shows the axons in a nerve bundle covered with the perineurium of the recurrent nerve. Formol.-Fix. BODIAN's Stain.

Fig. 14. A nerve trunk in the outer connective tissue sheath. Note the medullated and non-medullated nerve fibers. Formol.-Fix. BODIAN's Stain.

Fig. 15. A large ganglion found in the outer connective tissue sheath at the middle portion of the neck. Formol.-Fix. H-E Stain.

Fig. 16. Note the ganglia found in the outer sheath and intermuscular connective tissue of the tube. Formol.-Fix. H-E Stain.

Fig. 17. Photomicrograph of the multipolar nerve cells in a ganglion in the outer connective tissue sheath. Formol.-Fix. BODIAN's Stain.

Fig. 18. An intrinsic nerve trunk in the outer muscular layer. Furcation on its course. Formol.-Fix. BODIAN's Stain.

Fig. 19. Note the terminal nerve bundles arborizing repeatedly in the muscular coat. Formol.-Fix. BODIAN's Stain.

Fig. 20. Note the AUERBACH's plexus spreading between outer and inner muscular layers. Formol.-Fix. FLETCHER's Stain.

PLATE II

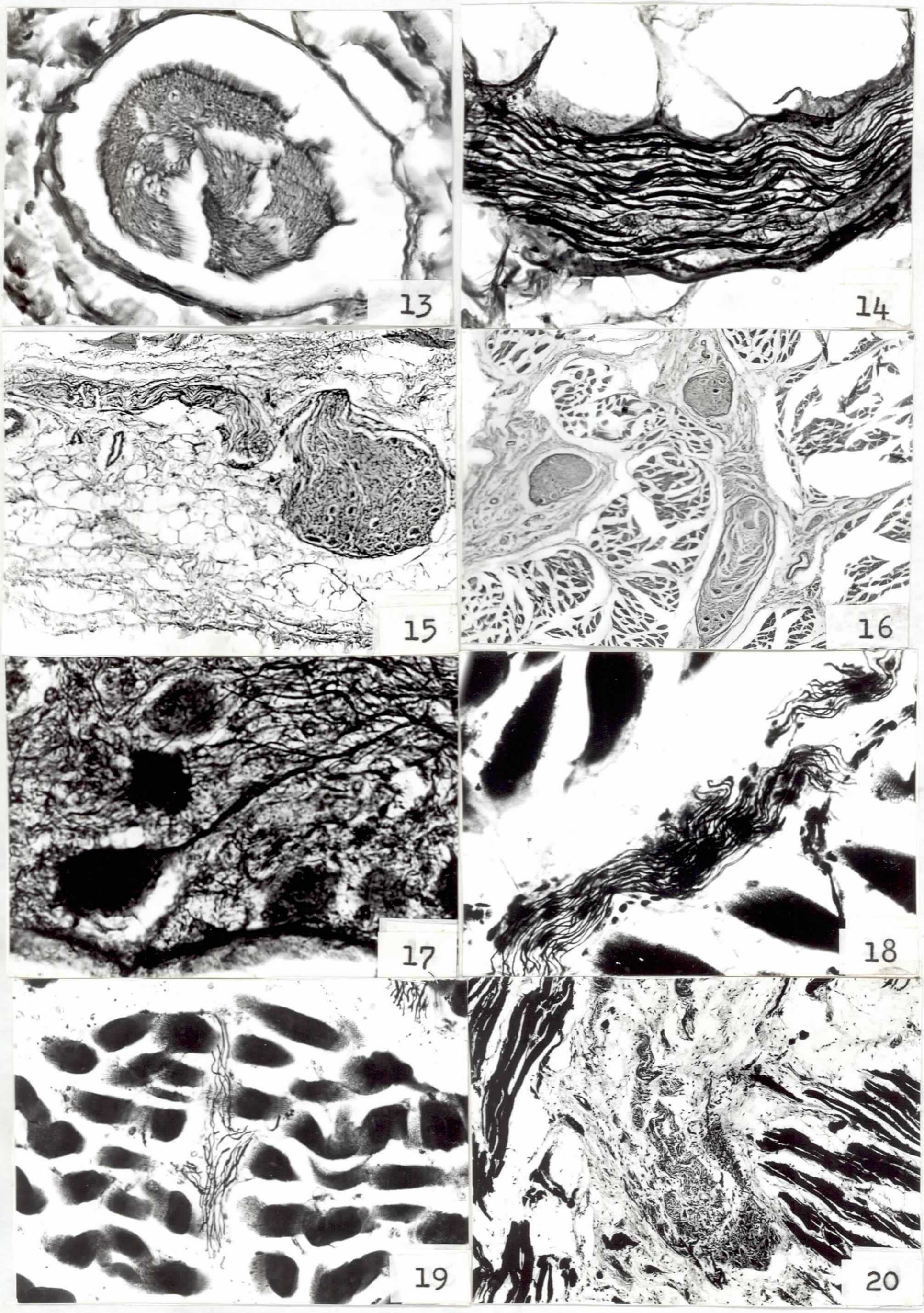


PLATE III

Fig. 21. Note the triplicate plexuses formed at the portion of origin of the oesophagus. Formol.-Fix. H-E Stain.

Fig. 22. Note the ganglion found in the outer muscular layer at the upper portion of the neck. Formol.-Fix. BODIAN's Stain.

Fig. 23. Photomicrograph of a ganglion in the intermuscular plexus. Formol.-Fix. FLETCHER's Stain.

Fig. 24. Note the delicated features of the nerve cells in the ganglion of intermuscular plexus. They are multipolar. Arrows indicates long neuraxis. Formol.-Fix. FLETCHER's Stain.

Fig. 25. Note the serpentine simple branched nerve termination (arrows) found in the ganglion of intermuscular plexus. Formol.-Fix. BODIAN's Stain.

Fig. 26. Nerve plexus found around the blood vessels (arrows) in the intermuscular connective tissue. Formol.-Fix. FLETCHER's Stain.

Fig. 27. Show the finding of the intramuscular nerve network. Formol.-Fix. BODIAN's Stain.

Fig. 28. Show the autonomic nerve fibers accompanying the SCHWANN's nuclei found between striated muscle fibers of the upper portion of the neck. Formol.-Fix. BODIAN's Stain.

PLATE III

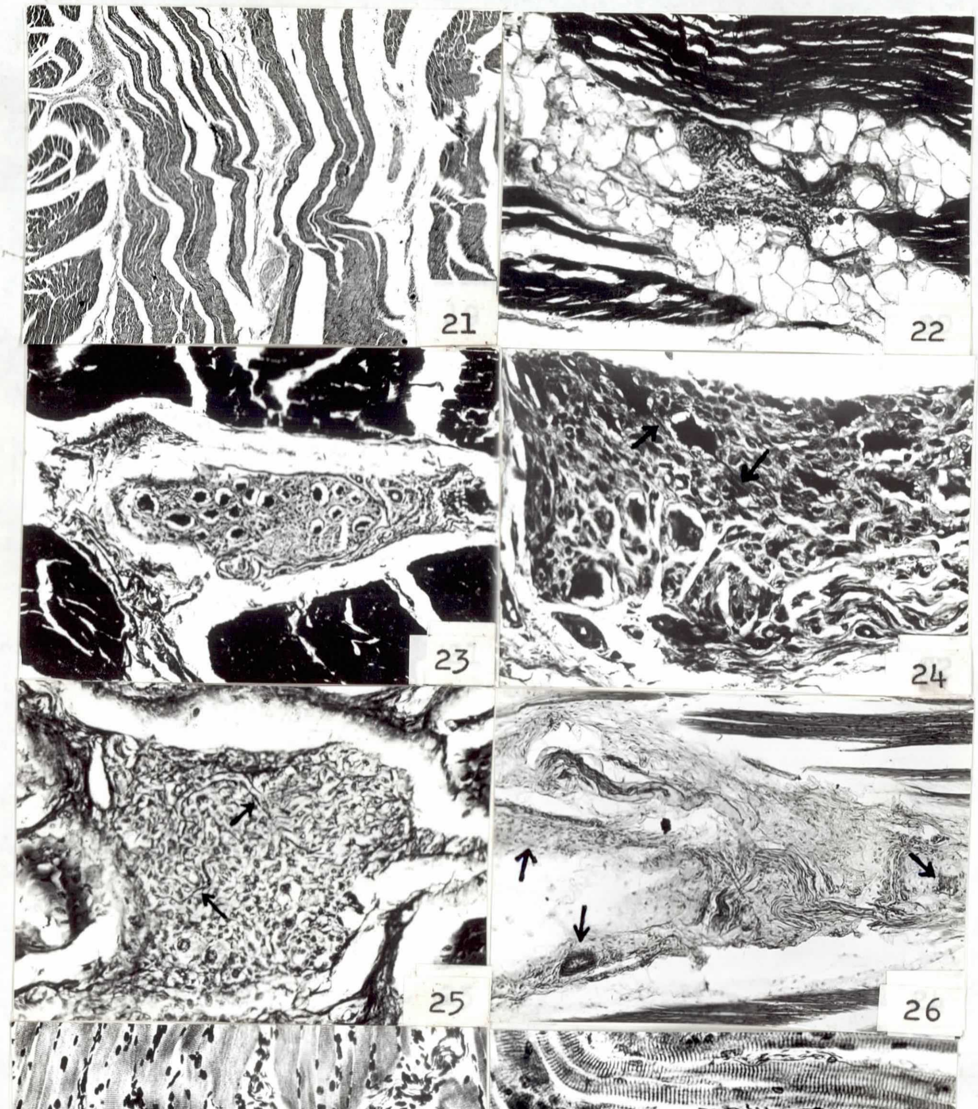


PLATE IV

Fig. 29. The terminal reticulum of the autonomic nervous system found in the crico-oesophageal muscle. Formol.-Fix. BODIAN's Stain.

Figs. 30 and 31. Note the free nerve termination found between muscle fibers of the upper end portion of the tube. Formol.-Fix. BODIAN's Stain.

Fig. 32. The palisade-like nerve apparatus (" terminaison en capuchons ") found in the inner muscular layer at the upper portion of the neck. Formol.-Fix. BODIAN's Stain.

Fig. 33. A nerve termination found in the muscularis which well resembles the corpuscle of MEISSNER. Formol.-Fix. BODIAN's Stain.

Fig. 34. Note the terminal minute fibers diverging radially from a terminal nerve bundle. The arrows indicate the divergent point. Formol.-Fix. BODIAN's Stain.

Fig. 35. Note the terminal minute fibers arborized from one of three terminal nerve bundles (arrows). Formol.-Fix. BODIAN's Stain.

Fig. 36. Furcation of the terminal minute fiber is showed be an arrow. Formol.-Fix. BODIAN's Stain.

PLATE IV

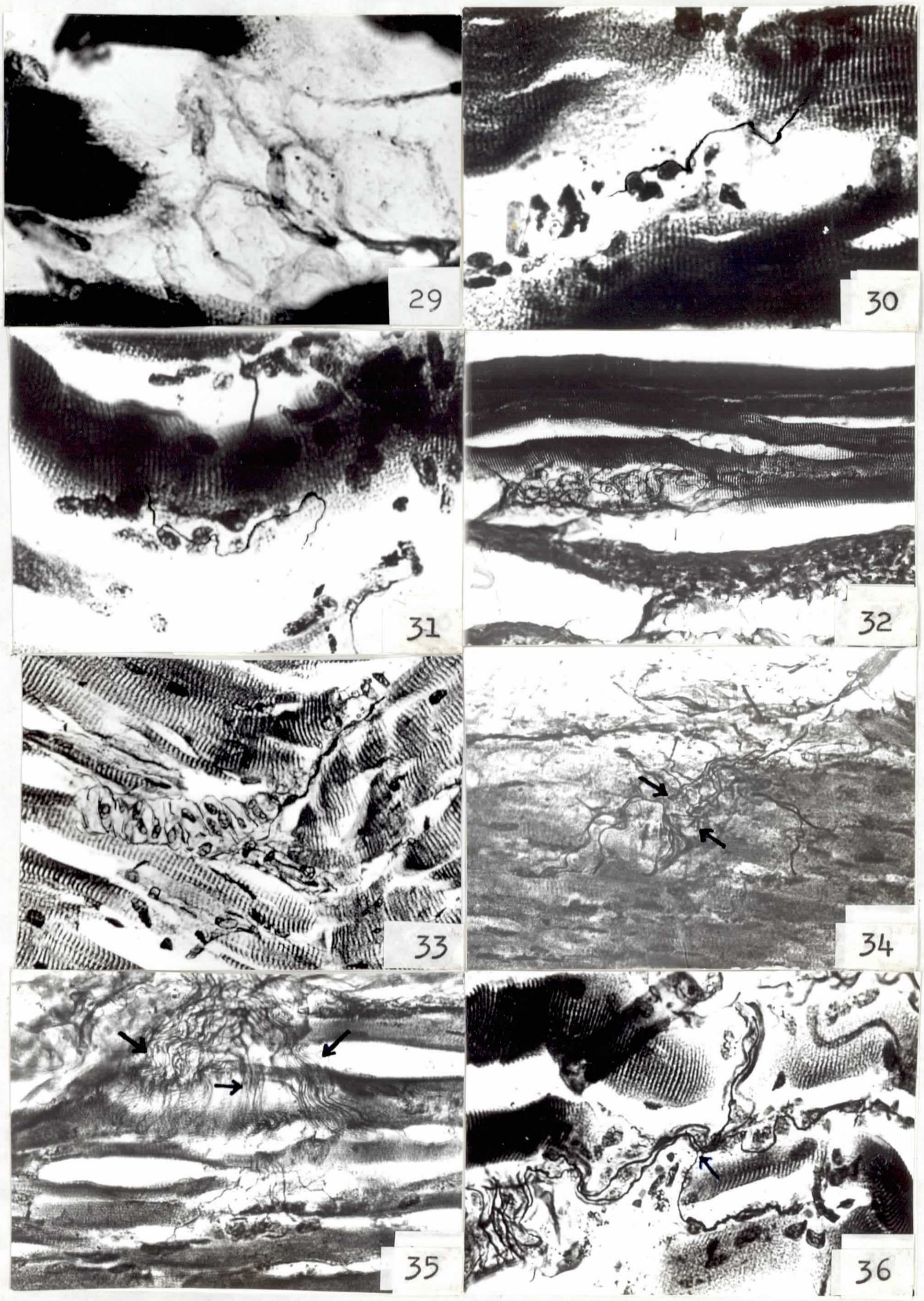


PLATE V

Fig. 37. Photomicrograph of the " en grappe " having two end plates and an accessory nerve fiber on a muscle fiber. Formol.-Fix. BODIAN's Stain. The detail will be shown in Fig. 72.

Figs. 38 and 39. Dorsal and lateral aspects of the typical moter end plate (type I) in the muscle tissue of the cattle oesophagus. Formol.-Fix. BODIAN's Stain.

Fig. 40. Two end plates formed on a muscle fiber innervating by an unitary nerve fiber. It is one pattern of the dual innervation. Formol.-Fix. BODIAN's Stain.

Figs. 41 and 42. Note the fine accessory nerve fiber (arrow) in the moter end plate. Formol.-Fix. BODIAN's Stain. Detail in Fig. 73.

Fig. 43. Note the ultraterminal nerve fiber (arrow) furcated from the nerve stem fiber of the multiple innervation. Formol.-Fix. BODIAN's Stain. Detail will be shown in Fig. 74.

Fig. 44. Photomicrograph of the moter end apparatus (type II) found in the crico-oesophageal muscle of the cattle. The accessory nerve fiber indicates by arrow. Formol.-Fix. BODIAN's Stain. Detail will be shown in Fig. 75.

PLATE V

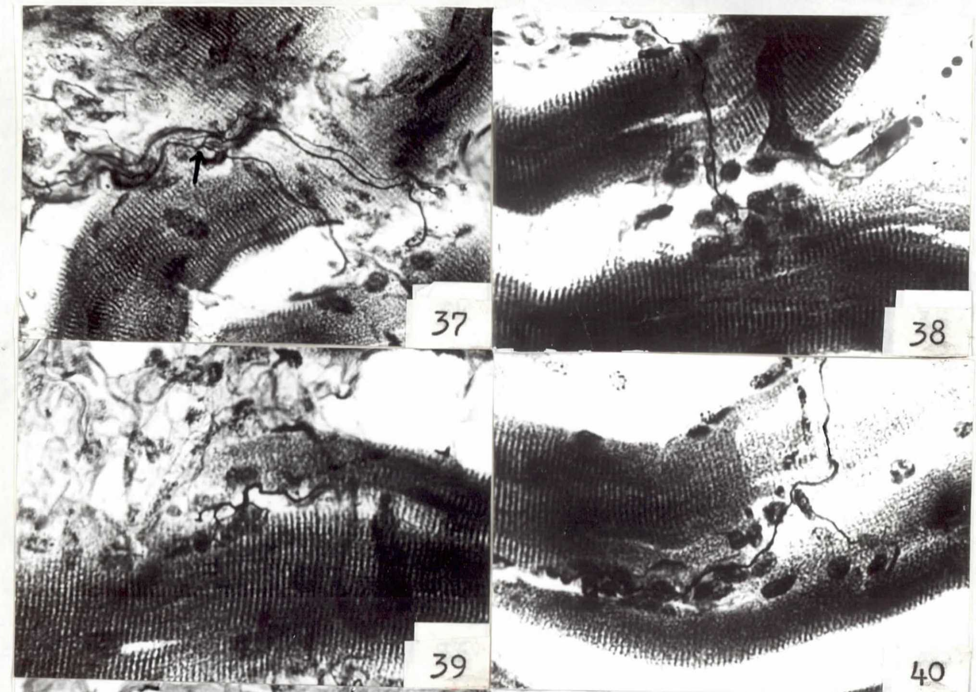


PLATE VI

Fig. 45. The ganglion of the submucous plexus found in the upper portion of the neck. The nerve cells varies in size. Formol.-Fix. FLETCHER's Stain.

Figs. 46 and 47. Note the submucous plexus and ganglion in the oesophageal vestibule. The nerve cells are distinguishable into two kinds ; argentophobe and argentophile. Formol.-Fix. BODIAN's Stain.

Fig. 48. The nerve bundle found between lobes of the oesophageal gland. Formol.-Fix. BODIAN's Stain.

Figs. 49 and 50. The nerve network (periductal plexus) found around the duct of the oesophageal gland. The thick fiber is sensory (arrow). Formol.-Fix. BODIAN's Stain.

Fig. 51. Note two thick medullated nerve fibers (arrows) found around the oesophageal duct. One enters into small gland loble, and the other terminates freely in the connective tissue. Formol.-Fix. FLETCHER's Stain.

Fig. 52. The fine nerve fibers (arrow) found in the terminal portion of the oesophageal gland. Formol.-Fix. BODIAN's Stain.

PLATE VI

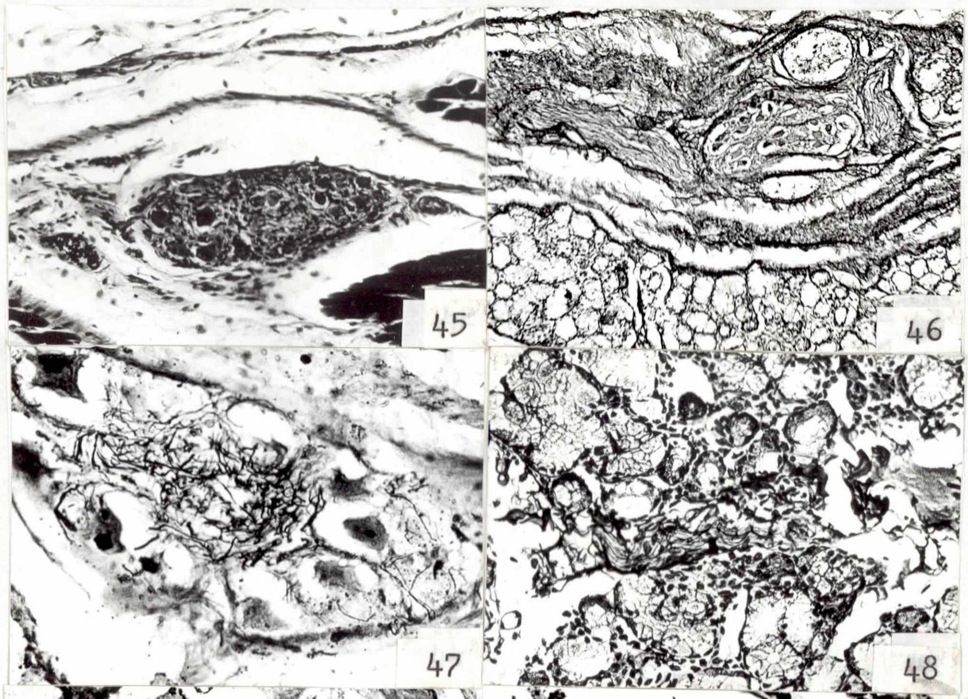


PLATE VII

Fig. 53. The nerve bundles in the submucous tissue of the upper portion of the neck. Alcoh.-Fix. CAJAL's Stain.

Fig. 54. Note the nerve bundle running along the blood vessel in the submucous tissue. Alcoh.-Fix. CAJAL's Stain.

Fig. 55. The nerve bundle winding towards the lamina propria. The arrow indicates the argentophobe fibers. Alcoh.-Fix. CAJAL's Stain.

Fig. 56. Note the mucous plexus in the upper portion of the neck. Formol.-Fix. BODIAN's Stain.

Fig. 57. Note the lateral aspect of the mucous plexus in the upper portion of the neck. Formol.-Fix. BODIAN's Stain.

Fig. 58. Note the serpentine nerve fiber in the lamina propria. Formol.-Fix. FLETCHER's Stain.

Fig. 59. Note the serpentine non-branched nerve fiber found in the lamina propria. Nerve fiber shows the frequent change in thickness. Alcoh.-Fix. CAJAL's Stain.

Fig. 60. Note the fine nerve fiber in the papilla of lamina propria. Formol.-Fix. BODIAN's Stain.

PLATE VII

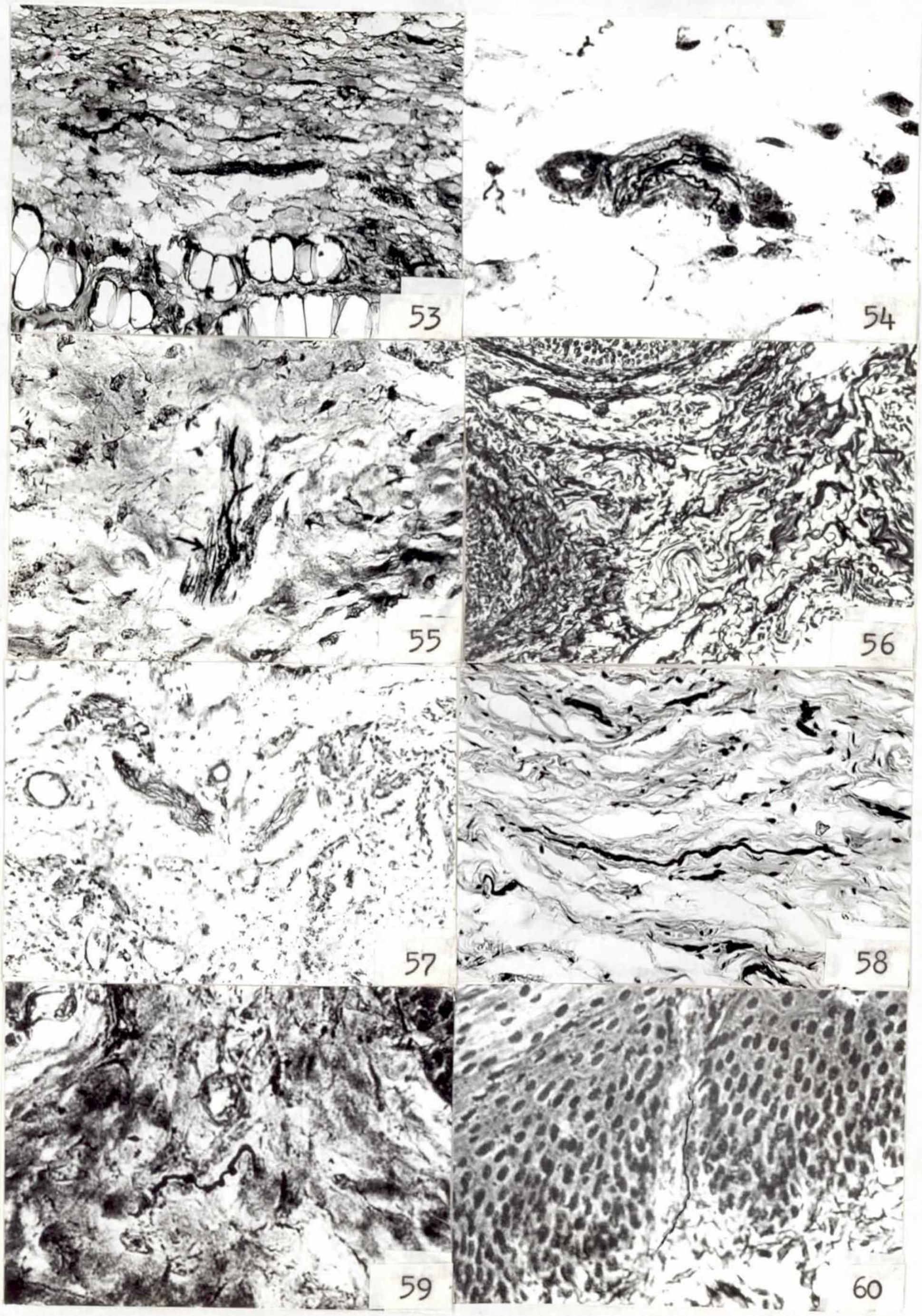


PLATE VIII

Fig. 61. Note the fine nerve fiber reached the top of the papilla of lamina propria. Alcoh.-Fix. CAJAL's Stain.

Figs. 62, 63 and 64. The non-branched intraepithelial nerve fiber found in the vestible and upper places of the oesophagus. Nerve fiber in Fig. 63 ends in small knob. Arrows shows the fragments of the mucous plexus. Formol.-Fix. BODIAN's Stain.

Fig. 65. Note a complete view of the oesophageal papilla of the adult cattle. Rectangle magnification shown in Fig. 70. Formol.-Fix. BODIAN's Stain.

Fig. 66. Note the traced nerve fibers (arrows) in the oesophageal papilla of the young case. Formol.-Fix. BODIAN's Stain.

Fig. 67. Note the serpentine nerve fiber in the lamina propria of the oesophageal papilla (arrow). Formol.-Fix. BODIAN's Stain.

Fig. 68. Note the nerve fiber lying beneath the epithelium of the oesophageal papilla. Formol.-Fix. BODIAN's Stain.

PLATE VIII

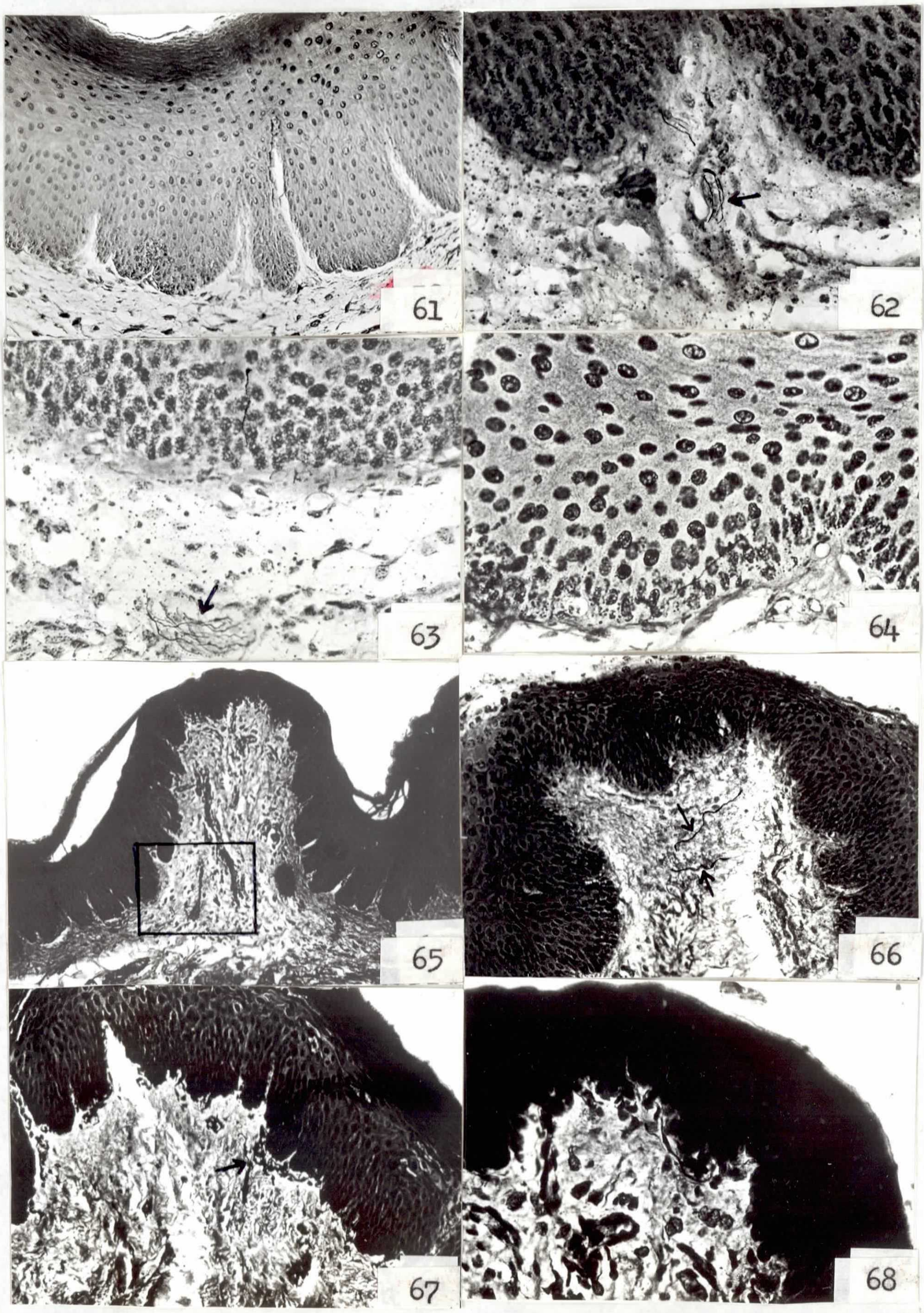


PLATE IX

Fig. 69. Note the fine nerve fibers terminating freely in the secondary papilla of lamina propria. Alcoh.-Fix. CAJAL's Stain.

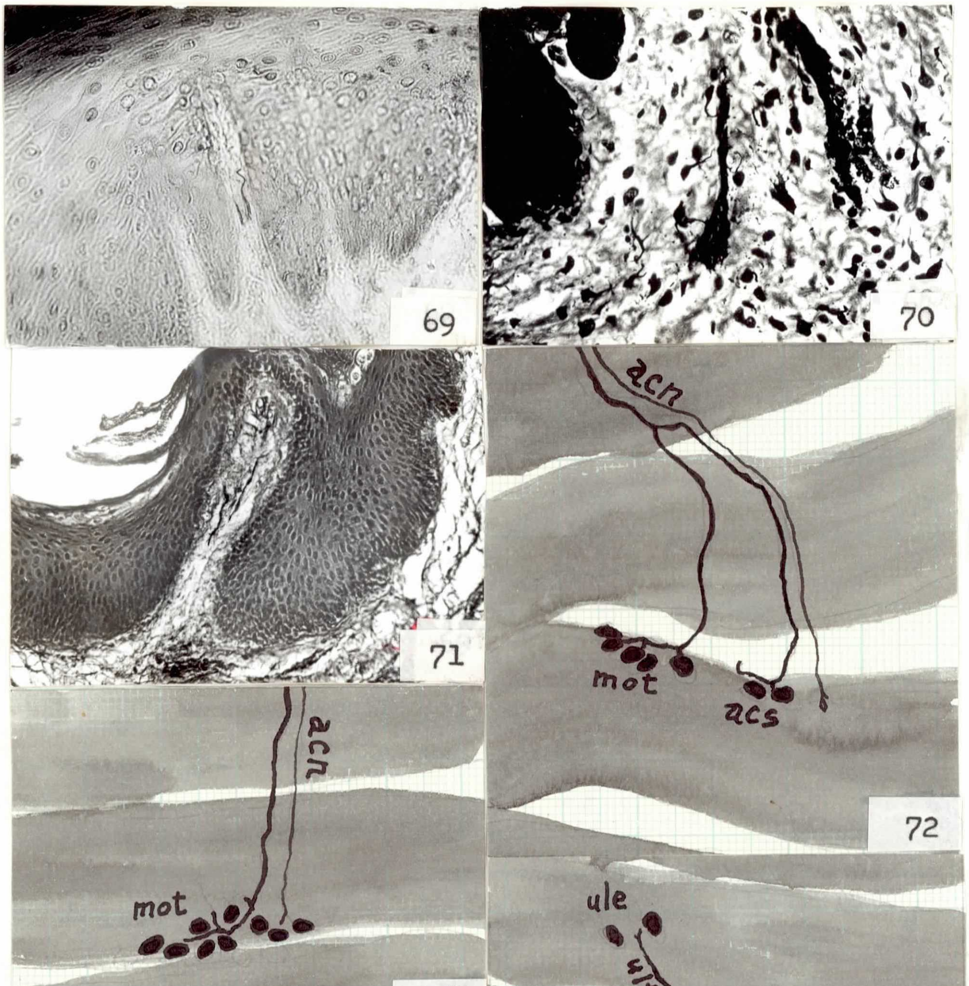
Fig. 70. Higher magnification of the rectangle part in Fig. 65. Note the distribution of the special nerve cells showing the unipolar, pseudo-unipolar or rarely bipolar shape. Formol.-Fix. BODIAN's Stain.

Fig. 71. Note the nerve fibers in the oesophageal papilla of the calf. Formol.-Fix. BODIAN's Stain.

Figs. 72, 73, 74 and 75. Abbreviation in the figures.

mot, Moter end plate ; acn, Accessory nerve fiber ; acs, Accessory end plate ; ult, Ultraterminal nerve fiber ; ule, Ultraterminal end plate.

PLATE IX



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