Histological Study of the Semilunar Ganglion of Dog.

Many researchers in the field have coped with the problem of elucidating the histology of the cerebral ganglia of man and other animals for nearly a century and have succeeded in achieving brilliant results in fairly extensive scope. We may mention with respect the works by SCHWALBE (1868), RETZIUS (1880, 1886), DAAE (1888), van GEHUCHTEN (1892), LENHOSSEK (1899, 1907), SPIRLAS (1896), KÖLLIKER (1896), DOGIEL (1896, 1897), PUGNAT (1899), CANNIEU (1898), HOLMGRÉN (1899), CAJAL (1906), MARINESCO (1906), NAGEOTTE (1906), BIELSCHOWSKY (1908), TAKEDA (1924, 1925), STÖHR (1928), OPALSKI (1930), KISS (1931, 1932), de CASTRO (1932), LEVI (1932), KINKEL (1932), BACSICH (1933), FISCHER & RANSON (1933), BARRIS (1934), BLAIR, BACSICH and DAVIES (1935), and more recently, the works with human cerebrospinal ganglia as materials by YAMASHITA (1939), SETO (1950), YOKOYAMA (1954) and MIKAMI (1953) of this laboratory have added many interesting contributions to the study on this subjects. In the footsteps of these illustrious predecessors, the authoress of this paper has tried to contribute what little she could to the accumulated knowledge on the histology of the cerebrospinal ganglia, and was granted the opportunity of making researches on the semilunar ganglion of the dog, an organ not much made of in the past as a theme of scientific study.

The many materials were fixed for a long time in 10% neutral formol, were cut into 40 µ flat frozen serial sections and stained with SETO's silver impregnation, and the large series of beautiful tissue sections thus obtained I subjected to minute microscopic examination. The results have been as reported in the following.

Individual Findings.

The nerve cells making up the cerebrospinal ganglia have been of old classified into the types of unipolar, bipolar and multipolar, according to the number of the nerve processes sent out per cell, and it has been accepted that since the bipolar cells are found only in embryos and their two processes unite in one postnatally, so that the cells are changed into unipolar form, the number of bipolar cells becomes very small after birth.
There have been not a few histologists who took multipolar cells to be of sympathetic nature or as representing pathological misformations.

YAMASHITA, however, has for the first in his study on the semilunar ganglion of man announced the assumption that the above three types of nerve cells are formed as separate classes since the time of embryonic development, that is, the unipolar cells are from the beginning unipolar and the bipolar equally specific formations not to be transmogrified into unipolar cells later on, and that the multipolar cells represent neither sympathetic cells nor pathological products, but are entities normal enough. More recently, an embryological study of human spinal ganglia by MIKAMI has resulted in endorsing the truth of these assumptions by YAMASHITA.

Thus, a series of studies in this laboratory has not only contributed in turning a new page in the embryology of sensory nerve cells in the cerebrospinal ganglia, but also in adding many a new finding to the informations on the histology of these parts.

In my study of the canine semilunar ganglia, I have found many a point resembling what has been reported concerning the human cerebrospinal ganglia in the above mentioned studies, but some findings apparently specific to the specimens of this animal have not been rare either, to my great interest. In the following, I will report with further detail on my study.

The nerve cells in the canine semilunar ganglia can be divided by their size into the large and the small cells, and by the number of their nerve processes into the unipolar, the bipolar and the multipolar cells, quite as those in the human GASSERIAN ganglion. The unipolar and the bipolar cells in the human ganglion can be further subdivided into the types of simple and complex by the form of the courses of their nerve processes (YAMASHITA), but in the canine semilunar ganglion, the situation is somewhat dissimilar, cells of a peculiar type seemingly specific to the dog being found in rather large frequency, beside the simple and the complex type cells, among the unipolar cells. The bipolar cells are mostly represented by simple type cells and complex type cells are very limited in occurrence, but specific cells are found here also, though on rare occasions only. Among the multipolar cells, beside the common type cells and the common fenestrated cells found in the human counterpart, specific fenestrated cells probably found in dogs alone are observed often enough.

Now, on the histology of unipolar cells. Such cells of complex type are usually found among the large cells, but not rarely among the small cells too. In the human semilunar ganglion, the axis cylinder emerging from a unipolar cell frequently is found to surround the mother cell
diverse complex course within the accessory cell plasmodium (YAMASHITA, Figs. 1 and 3), but in the canine ganglion, axis cylinders running such complicated courses surrounding their unipolar mother cells are found only very rarely. Usually, the axis cylinders of the complex type cells run more or less complex spiral course near their process poles and then out of the connective tissue capsules. In most cases, a dense aggregation of accessory cell nuclei is found near such a process pole.

Fig. 1 shows a large cell of unipolar complex type. Here, a very thick axis cylinder is found to run unipolarly a rather steep spiral course before running out of the capsule. Near the process pole many specific nuclei are found in a group in the accessory cell plasmodium. What is of interest is that this axis cylinder is provided with a thick myelin sheath as soon as it passes out through the capsule. Such complex type cells as illustrated in this figure are extremely abundant in the canine semilunar ganglion. Pole-standing type cells of even more complicated construction, however, are also of frequent occurrence in the canine semilunar ganglion. A large cell showing a similar spiral course of a thick axis cylinder near the process pole is illustrated in Fig. 2, but here the spiraling of the course is much gentler than in the former. This cell may be placed be-
between the complex and the simple cells in its type.

Simple type cells among the unipolar are mostly small ones (Fig. 3), but large unipolar cells of simple form are not rare at all (Fig. 4). As shown in the figures, in such a cell, a single nerve process, runs an extremely simple course before going out of the capsule. In Fig. 3, we find the axis cylinder consisting in a thin fibre, but in Fig. 4, it is of an intermediate size. In general, the small cells send out thinner axis
cylinders than the large-sized cells. The axis cylinder appearing in Fig. 3 is seen to bifurcate extracapsularly and also sending out a very fine collateral.

The specific type unipolar cells may be called a variation of the complex type cells. In a cell of this type, the nerve process sends out during its spiral or ansiformed course some rami, which after a while return to their mother fibre, to form quite irregularly shaped fenestrae of varying size in the running course of a nerve process. The nerve branches forming such fenestrae are sometimes thick enough, but sometimes are merely very fine collaterals. Often very complex specific type cells are found, in which a number of such windows are found in serial succession.

Fig. 4. A large unipolar cell of simple type with a comparatively thick axis cylinder found in a canine semilunar ganglion. c fine collateral running intracapsularly. b extracapsular bifurcation. Same staining. ×800, reduced to 3/5.

LENHOSSÉK, in his study on the spinal ganglia of man, dog, cat and horse published in 1907 points out as very interesting that in horse alone he could find specific unipolar cells similar to those I have found in the canine

Fig. 5. A large unipolar cell of specific complex type found in a canine semilunar ganglion. 2 windows are formed by thick rami in the spiral course of the axis cylinder. Same staining. ×800, reduced to 3/5.
semilunar ganglion. This proves that the specific type unipolar cells are not strictly specific to dogs but are found also in some other mammals. As no cells of this type, however, have ever been found in the cerebrospinal ganglia of man, they are still very interesting entities from the view-point of comparative anatomy.

Fig. 6. A large unipolar cell of specific complex type found in a canine semilunar ganglion. Many windows are formed by thin collaterals in the spiral course of the axis cylinder. Same staining. ×800, reduced to 3/5.

Fig. 7. Ditto. Same staining. ×1000, reduced to 3/5.

As mentioned above, the axis cylinders sent out from large cells are usually thick in size (Figs. 1 and 2) and the smaller the size of the cell, the thinner becomes its axis cylinder, as might be readily inferred from
the figures introduced in this report. This interrelation of the size of the cell and that of its axis cylinder applies not only to the unipolar, but also to the bipolar and the multipolar cells. The axis cylinders of unipolar cells bifurcate into the peripheral and the central fibres by T- or Y-shaped branching (Fig. 8). The distinction between the peripheral and central fibres is clear enough, in unipolar as well as bipolar and multipolar cells. Some former neurologists maintained that the central fibres are thinner than the peripheral fibres, but in the semilunar ganglion of dog I have examined, such a rule does not prevail. Namely, I found that the two branches sent out by the axis cylinder of a unipolar cell after running varying distance beyond the connective tissue capsule, though sometimes of rather different thickness, are often enough of nearly the same size, and even the cases where the thicker fibres run centrally and the thinner ones peripherally are not rare either (Fig. 8).

It is also nothing rare to find the axis cylinder of a unipolar cell to bifurcate before running out of the capsule. Quite as in man and other mammals, the axis cylinder of the cells in the semilunar ganglion of the dog often send out very fine intra- and extracapsular collaterals in their courses (Fig. 4).

Fig. 8. Bifurcations of axis cylinders of unipolar cells into central and peripheral fibres of varying size found in canine semilunar ganglia. c central- and p peripheralwards. Same staining. ×1000, reduced to 3/5.
According to RETZIUC (1880), van GEHUCHTEN (1892), LENHOSSEK (1899) and CAJAL (1906), since the unipolar cells in the cerebrospinal ganglia are always originated in bipolar cells by transformation, it has been accepted that the number of bipolar cells becomes very limited in maturer ages. In fact, the number of bipolar cells in the said ganglia of adult man and mammals is much smaller than that of the unipolar cells and not a few researchers have failed to remark their existence at all, only DOGIEL having reported them as found in the spinal ganglia of the cat (1896) and the horse (1908), CAJAL (1906) in the human ganglion nodosum and the vagal ganglia of some mammals, RANSON (1912) in the spinal ganglia of the dog, KINKEL (1932) in the spinal and the vagal ganglia of some birds and TAKEDA (1924) in the semilunar ganglion of the ox.

YAMASHITA, however, has succeeded in finding a rather large quantity of bipolar cells existing in the human semilunar ganglion and was led to suspect seriously the accepted embryological notion on the origin of unipolar cells. He began to doubt the theory of derivation of the unipolar cells from the bipolar, and was inclined to assume that the cells of both the types come into existence as separate types from the first. The truth of this assumption was subsequently very clearly demonstrated by MIKAMI (1953) in his study on the developmental study of human embryos.

![Fig. 9. A large bipolar cell of simple type found in a canine semilunar ganglion. Same staining. ×800, reduced to 3/5.](image)

Now, in my sections of the canine semilunar ganglion, the existence of bipolar cells was demonstrated, though their number was considerably smaller than those in the human cerebrospinal ganglia. These bipolar cells are generally of the simple type, that is, the intracapsular courses
of their two processes are usually very simple (Fig. 9). But bipolar cells whose axis cylinders run rather complicated courses before passing beyond the connective tissue capsule are not rare either. On rarer occasions, some bipolar cells with fenestration in the intracapsular courses, as in the specific unipolar cells described above, were detected. For example, in Fig. 10, one of the two nerve processes emerging from a nerve cell runs out of the capsule after running a simple course, while the other shows a rather complex spiral course during which distinct fenestrae are formed.

The multipolar cells found in the semilunar ganglion of the dog are larger in quantity than those in the human ganglia, and are sometimes rather widely different from the latter in form, as alluded to in the above. In fact, in the human semilunar ganglion beside many so-called common multipolar cells with a few short nerve processes ending freely, there are found here and there nerve cells of which the processes run simple courses returning to the mother cells to form the so-called fenestrated cells, or with end-plates at the tips of their processes. In any case, however, the running courses of the nerve processes of these multipolar cells are very simple.

Such extremely simply formed multipolar cells as may be found in human cerebrospinal ganglia are found only in a very limited number in the canine semilunar ganglion. For example, such a multipolar cell of simple type as shown in Fig. 11, showing a simple fenestration and a short process ending in a free point, is indeed very rare in the canine ganglion. In man, multipolar cells with end-plates at the tips of their short processes are also of rather frequent occurrence, but similar cells are found in extremely rare existence in the canine semilunar ganglion (Fig. 12).

In the semilunar ganglion of the dog, the largest number of the multipolar cells have nerve processes running very complicated and peculiar courses, as described below. Many fenestrae are formed in the courses and I wish to call these cells specific fenestrated cells. In such a cell,
the nerve processes emerging at random intervals from the cell surface come into mutual anastomosis to form a number of fenestrae, and then units into one axis cylinder. In short, a cell of this type sends out many processes which fuse into a single nerve fibre after complex fenestration. This type comprises the simple and the complex subtypes.

A specific fenestrated cell of the simple subtype is shown in Fig. 13.
In such cells, as illustrated here, fenestration is limited to one of the poles of the cell, and the fenestrae are usually small in size and simply circular or elliptic in shape. Similar cells have been found also in the human semilunar ganglion (YAMASHITA, Fig. 11) and in the same of oxes in a large number (TAKEDA).

In a specific fenestrated cell of the complex subtype, the nerve processes do not emerge from definite poles but at some rather large intervals from the surface, run peculiar winding courses and then undergo mutual nervous anastomosis to form quite irregular-shaped fenestrae of varying size, before coming together into an axis cylinder. This axis cylinder also very frequently runs a characteristic winding or spiral course. The cell of this type shown in Fig. 14 is of the form most prevalent among the multipolar cells of this subtype. Fig. 15 shows a specific fenestrated cell with nerve processes running even more irregular and complex courses than that seen in Fig. 14.

Of the specific fenestrated cells of these two subtypes, the simple ones seem to be usual in the cerebrospinal ganglia of man and all other mammals, but those of the complex subtype are never found in man and seem to be not always found in the cerebrospinal ganglia of other mammals. For example, CAJAL (1906), in his study of the vagal ganglia, has found such cells in the ass and the sheep but not in the other mammals he examined, while LENHOSSEK, in his study of the spinal ganglia.
Fig. 14. A large specific fenestrated cell of complex subtype found in a canine semilunar ganglion. Details in the text. Same staining. ×800, reduced to 3/5.

Fig. 15. A large specific fenestrated cell of complex subtype found in a canine semilunar ganglion. Fenestration is further complicated than in Fig. 14. Same staining. ×800, reduced to 3/5.

of man and some other mammals, has never encountered such cells. TAKEDA (1933) seems to have failed in detecting this type of nerve cells in the dog semilunar ganglion in his study.
The above described multipolar cells found in the semilunar ganglia of the dog have only a small number of nerve processes, which, however, are quite dissimilar from those of sympathetic nerve cells in their nature and running courses, and since their long processes run central- and peripheralwards, they must be of sensory nature. KISS (1932) has found numerous multipolar cells in his osmic acid-stained sections of human and mammalian spinal and semilunar ganglia and took them to be sympathetic cells. The reports of BACSICH (1932) and of BLAIR, BACSICH and DAVIES (1935) give credence to this opinion of KISS, but the majority of the researchers in the field looked upon these findings of KISS as mere artefacts born of faulty staining and made little of them. A few later neurologists have advocated the theory of KISS, but my study of the semilunar ganglion of the dog has revealed, in agreement with the findings of the majority of the researchers, and in particular, with those of YAMASHITA in human semilunar ganglion, of MIKAMI in the spinal ganglia of human embryos and of YOKOYAMA in the vestibular ganglia of human embryos, that no sympathetic ganglion cells are to be ever found here.

Summary.

The nerve cells found in the semilunar ganglion of the dog are classifiable into large cells and small cells by size, and by the number of their nerve processes into unipolar, bipolar and multipolar cells.

The unipolar cells in the canine semilunar ganglion can be classified into the simple type and the complex type cells, as found in human ganglia, but many were found to show a specific type not observable in the human counterpart.

Simple type unipolar cells are chiefly found among the small cells, and have single nerve processes which run very simple intracapsular courses before running out of the capsule. The unipolar cells of complex type are usually large cells and their nerve processes run spiral courses at one of the poles of the cells and then emerge from the capsule. Such unipolar cells with their processes running intricate courses surrounding the cell bodies, as often found in man, are only very rarely found in the semilunar ganglion of the dog.

The specific type of the unipolar cells in the canine semilunar ganglion seems to represent a variation of the complex type. In a cell of this type, the nerve process sends out some rami during its spiral course, which run back to the mother fibre to form quite irregular-formed windows of varying sizes. Since similar cells are found in the spinal ganglia of horses too (LENHOSSEK), they are presumed to be present in the cerebrospinal ganglia of some non-human mammals.
In nerve cells of any type, thick axis cylinders usually originate in large cells and thin cylinders in small ones, but exception are not rare. The axis cylinders of the unipolar cells divide into peripheral and central fibres by T or Y-shaped bifurcation, but no rule was found concerning their relative thicknesses. This applies also to the central and peripheral fibres of the bipolar and the multipolar cells equally well. The bifurcation of the axis cylinders of the unipolar cells generally occur without, but not rarely also within, the connective tissue capsules. The axis cylinders of the nerve cells of any type often send out thin collaterals.

Bipolar cells too are found in the semilunar ganglion of the dog, though only in a very limited number. The formerly accepted theory that such bipolar cells represent infantile forms of unipolar cells has been refuted by YAMASHITA and MIKAMI of this laboratory, and my study also led me to deny such a hypothesis. The intracapsular courses of the two processes of such a bipolar cell are usually very simple in arrangement, that is, the cells are mostly of simple type, but sometimes, more complex-typed ones with spiral or fenestrated processes are found in existence.

The multipolar cells in the semilunar ganglion of the dog are found in a larger number than in man, and in their formation, are sometimes quite dissimilar from those in the human ganglia. Namely, such common multipolar cells, simple fenestrated cells and nerve cells with endplates on their processes are very rare in the dog, but the majority of them consist in my so-called specific fenestrated cells with nerve processes running complex and peculiar courses.

In such specific cells, their nerve processes emerge at varying distances on the surface of the cell bodies, come soon into mutual anastomosis to form a number of windows and then unite into single axis cylinders. These cells comprise those of simple and of complex types. In a simple-typed cell, the fenestration occurs at one of the poles of the nerve cells so that the formation is rather small and simple, but in a complex-typed cell, the nerve processes emerging at random distances from the cell surface make very variegated windows, before passing over into an axis cylinder generally running a winding course also peculiar to a cell of this type. Such specific multipolar cells of the simple type have been found also in the cerebrospinal ganglia of man and all other mammals, but the complex type is foreign to human ganglia and seems to be found only in some limited species of mammals.

The multipolar cells in the semilunar ganglion of the dog, whatever their type of formation, cannot be looked upon as belonging to the sympathetic system, but as possessing sensory nature, quite as those in the human cerebrospinal ganglia.
内容抄写

大半月状神経節の神経細胞は大細胞と小細胞に分けられ、之等は更に神経突起の数によって単極、2極、多極細胞に区別される。

単極細胞は神経突起の走行状態から更に単純型、複雑型及び特殊型に分けられる。単純型は小細胞に多く見られ、1条の神経突起の走行は単純、反し複雑型は複雑な走行に見える。神経突起は多くの場合自己の細胞の1極に於て複雑な螺旋状走行を示す。大半月状神経節に見られる種々の細胞口の複雑に走行する神経突起数の単極細胞は犬では殆ど見られな

い、特殊型では神経突起の螺旋状走行上2 - 3の分歧が現われ、之等は再び神経突起に帰り種々の走行の不規則な神経細胞を形成する。本型は人間以外の哺乳動物の腸管神経節に見られると考えられる。

何の種の細胞でも大細胞からは太い神経突起、小細胞からは細い神経突起が出るのが一般であるが、時には例外も認められる。単極細胞の神経突起のT状状やY状分歧による両神経の太さの差異に就ては一定の法則は見られない、此事は2極及び多極細胞に於ける両神経突起にも当てはまる。何の種の細胞に於ても神経突起から分岐細い副神経の発生を見る。

犬半月状神経節にも2極細胞が少量に発見される。そして私もより2極細胞を初等型とする古い学説に反対し難い。2極細胞の神経突起の走行は多くは単純に行われるが（単純型）、中には螺旋走行（複雑型）及び単極細胞に於けると同様な走行（特殊型）を示すものもある。

犬では多極細胞は人間に於けるよりも多く見られ、且つ形状に於て人の場合ととなり異なるものがある。即ち人に見られる単純性有窓型や終末板型は犬では甚だ少なく、大数は特殊有窓型で表われる。之は多くの神経突起が互に吻合により多数の窓を作り、然る後1条の細胞に移行するもので、本型は更に単純型と複雑型とに区別される。前者では窓形成が細胞の1極に於て行われ、共規模も小さいが、後者では窓形成が細胞の全表面に行われ、然る後度数走行する1条の軸索突起に移行する。この複雑型は人間では見られず、特定の哺乳動物に限り見出される様である。尚お以上何の種の多極神経細胞も神経突起の性状からして交感神経細胞に属せず、知覚性のものである。
References.