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LOCALIZATION IN THE GANGLION SEMILUNARE OF THE CAT

WILLIAM F. ALLEN
Department of Anatomy of the University of Oregon Medical School, Portland, Oregon

ELEVEN FIGURES

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INTRODUCTORY

Some time ago, while studying the distribution of the ascending trigeminal mesencephalic root fibers after destroying the ganglion semilunare, and observing that the eye on the lesion side always went blind as a result of severing the eyelid reflex, it occurred to the writer that the cell bodies of the three great branches of the nervus trigeminus might be located more or less in definite circumscribed areas. If so, the possibility suggested itself, in case of trifacial neuralgia involving the nervus mandibularis or n. maxillaris, of being able to destroy these areas in the ganglion without injuring the cells of the nervus ophthalmicus.

An examination of the literature has revealed a great number of investigations on nerve components, segmental arrangement, early development of the various cranial ganglia, and on the peripheral and central distribution of the trigeminal fibers, but so far as could be ascertained nothing has been done on the localization of the cells of the three great trunks of the nervus trigeminus in the ganglion semilunare.

The work on nerve segmentation and nerve components is entirely too bulky to even mention. Some idea of it can be obtained by consulting the various papers of Allis, Cole, Gaskell, Johnston, Herrick, Strong, von Kupffer, and others. Landacre found the semilunar ganglion of the catfish to be formed from a lateral mass of cells composed of neural crest and mesoderm. Dixon and Streeter represent the human ganglion semilunare as being formed from a single undivided mass of neural crest. Giglio-Tos shows the semilunar ganglion in his schematic figure 4 to be formed from the fusion of three 'progangli primitivi neurali' with three corresponding 'progangli primitive mesocefalici (epibranchiali)'; forming three primitive trigeminal proganglia designated as 'proganglio neurale oftalmico,' 'proganglio neurale mascellare,' and 'proganglio neurale mandibulare.' These three ganglia are ultimately fused in a single ganglion.

In reptiles both Fisher and Watkinson have described the ganglion semilunare as being composed of two distinct ganglia, an ophthalmic ganglion and a maxillary-mandibular ganglion. This is obviously a striking resemblance to the embryonic condition of the lower vertebrates. On the other hand, both Ogushi and Hanson deny this claim and state that the ganglia semilunare consists of a single ganglion. They, however, note that ganglion cells have migrated a short distance into the nervus ophthalmicus.

A paper having some bearing on this problem is Professor Perna's studies on the alteration of the semilunar ganglion after the extraction of various teeth and all of the teeth from one-half of the upper and lower jaws of monkeys and dogs. This area of altered cells is shown in his figures I to V to be a triangular mass opposite the junction of the maxillary and mandibular nerves; the base of this triangle is situated peripherally at the junction of these two nerves and the apex is located more centrally in the ganglion. According to the author, the removal of the premolars and molars from one side produces a degeneration of the cells in the region of the apex of the dental triangle, namely, that part nearest the center of the ganglion; while extraction of the canines and incisors causes a similar change in the opposite, base or peripheral end of this triangle. In some experiments where the molars and premolars were removed from the upper or lower jaws there is said to be no appreciable difference in the areas of altered cells; while extraction of the canine and incisors from the upper jaw produced an area of degeneration that was continuous along the margin of the maxillary nerve, and removal of the same teeth from the lower jaw resulted in a similar area of altered cells along the border of the mandibular nerve.

MODE OF PROCEDURE AND MATERIAL

The method of investigating this problem consisted chiefly in making a survey of the chromatolytic cells in a Nissl series of a ganglion semilunare after one of its main afferent trunks had been severed. Recourse was also made to several Cajal series and to normal Nissl series. In every instance the lesion was made on the left side, and the animal was killed on the fifteenth or eighteenth day after the operation, more often on the latter. After killing the animal, the semilunar ganglion of the lesion side was carefully dissected out of the base of the skull, leaving intact a considerable portion of both roots and the three afferent trunks. It was then fixed in a solution composed of 50 cc. of 10 per cent formalin, 50 cc. of 95 per cent alcohol, and 5 cc. of glacial acetic acid; embedded in paraffin; cut serially 15 μ thick; stained overnight in a $^1/_5$ per cent solution of toluidin blue at a temperature of 38°C.; destained in the process of dehydration, and cleared in Johnston's xylol-castor oil mixture. A number of normal ganglia from the right side were treated in the same manner for controls, while other ganglia were stained after several modifications of Cajal's silver method.

Excepting two series mentioned below, which are from guinea-pigs' ganglia, the remainder are from cats' ganglia. In all of the operations no other nerves were disturbed excepting those that were cut. The adjacent blood vessels were interfered with as little as possible, and in no case was there any infection.

In series numbered 84, 203, and 204 the left nervus maxillaris was cut in the cephalic end of the orbit. The incision in each case was made in front of the eyeball, leaving the muscles of the eye undisturbed. No damage was done to any of the branches of the nervus ophthalmicus.

In series 193 the left nervus frontalis was severed as it crossed the upper surface of the eyeball. In series 81 and 208 the eyeball was removed from the orbit and all branches of the nervus ophthalmicus were cut without injuring any of the branches of the nervus maxillaris.

In each of the following series an incision was made along the inner caudal half of the left mandibula to the depth of the foramen mandibulare without injuring any of the neighboring nerves or blood vessels. In series 196 and 200 the left nervus alveolaris inferior was cut at its exit from the foramen mandibulare. In series 197 and 202 the nervus lingualis was severed close to its union with the n. alveolaris inferior. In series 207 the n. mylohyoideus was cut close to its junction with the n. alveolaris interior, the n. alveolaris inferior was severed at its exit from the foramen mandibulare and the n. lingualis was cut close to its union with the n. alveolaris inferior.

In series 194 and 195 the nervus alveolaris inferior and the n. maxillaris were severed in the guinea-pig after the same manner as in the above cat operation.

Of these series the ones in which the nervus maxillaris was cut proved to be the best for demonstrating the general ground-plan of the ganglion semilunare for the reason that the n. maxillaris enters the ganglion between the n. ophthalmicus and the n. mandibularis. In fact, any one of these series would give an accurate idea of the arrangement of the cells of the three main afferent nerve trunks. The other series in which the n. opththalmicus, its different components, and various branches of the n. mandibularis were cut, threw additional light upon the arrangement of the cells of these branches of the main trunk and in addition corroborated most of the deductions obtained from a study of the series in which the n. maxillaris was severed. Of the three series in which the n. maxillaris was cut, series 203 turned out to be the best and was selected for the bulk of the study of this problem.

At the outset it was obvious that in order to obtain a proper conception of the arrangement of the chromatolytic cells in series 203 it would be necessary to make a reconstruction of this series. Consequently, the graphic reconstructions shown in figures 1 and 2 were prepared after the following manner: Accurate tracings of every fourth section were made with the aid of a projection drawing apparatus, using a magnification of 25 diameters. In each tracing the areas of chromatolytic and normal cells were accurately blocked in, and afterward checked up with a higher magnification. A horizontal line, dorso-ventral line (projection line A-B), was drawn across the center of one of the sections taken from the middle of the series. This line was added to the preceding and following sections by accurately fitting these tracings over the middle tracing and copying the line. In like manner the projection line was transcribed to all of the preceding and following tracings. With a pair of dividers the various structures from the upper side of each tracing (median side of the ganglion) and from the lower side of each tracing (lateral side of the ganglion) were projected on its corresponding vertical millimeter line, above and below the projecting line A-B, on one or the other of the sheets of millimeter paper that are to represent dorsal or ventral views of the ganglion; the end product when copied to a piece of drawing-paper with the various ganglionic areas shaded differently produced figures 1 and 2. It should be recorded that the reconstructions would have assumed slightly more accurate proportions if every third section had been drawn instead of every fourth.

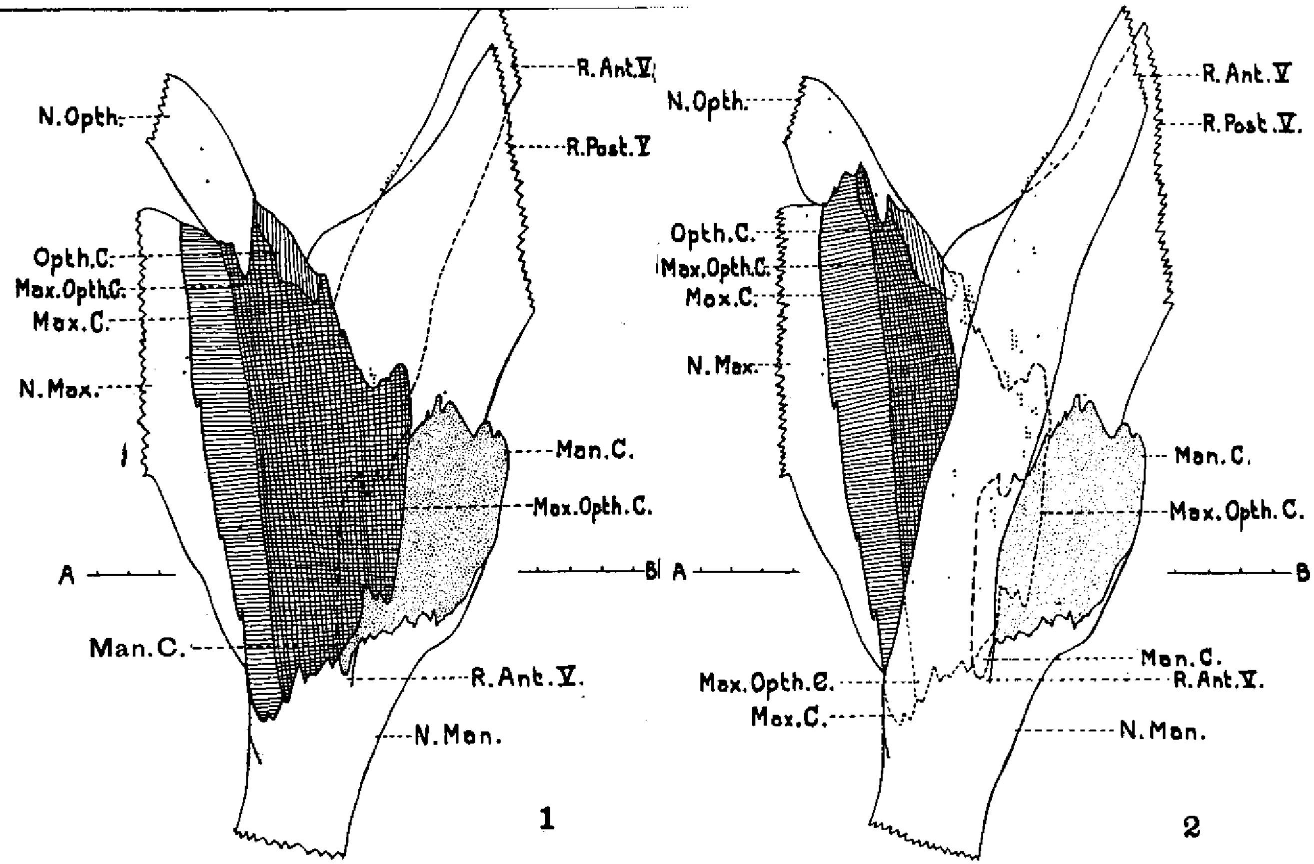


Fig. 1 Dorsal graphic reconstruction of the left ganglion semilunare from Nissl series no. 203 in which the left nervus maxillaris was cut in the cephalic part of the orbit. × 6⅓.

Fig. 2 Ventral graphic reconstruction of the left ganglion semilunare from the same series as above. × 6⅓.

In addition to the series described above, the writer possesses several cat semilunar ganglia that have been preserved in an alcohol-chloroform mixture—a solution which makes them somewhat transparent and suitable for surface examination. After the enveloping membrane had been dissected away, some of these ganglia were studied with a lens in bright sunlight in the above solution. The upper and lower surfaces of these ganglia resemble the corresponding surfaces of the human semilunar ganglion, excepting that the visible cell mass appears in the form of a narrow rectangular ridge instead of being more or less semicircular. Beginning medially, this ridge of cells passes laterally and caudally, crossing the trigeminal roots rather obliquely. One of these ganglia in which the capsule had been entirely dissected off appeared, both dorsally and ventrally, to be more or less separated into an inner ophthalmic-maxillary portion and a lateral-caudal mandibular division. A considerable portion of the latter is overarched by the wall of the tympanic bulla.

EXPLANATION OF THE FIGURES

Figures 1 and 2 are from dorsal and ventral graphic reconstructions of a Nissl series of a cat's ganglion semilunare in which the nervus maxillaris had been cut in the orbit. In these reconstructions the region of nervus maxillaris cells is represented by horizontal shading, the n. ophthalmicus cells by vertical shading, and the combined cells by both vertical and horizontal shading, while the area of n. mandibularis cells is stippled. The large round dots signify isolated cells, either normal or chromatolytic, or possibly in some instances round wandering cells. Figures 3 to 10 are from transverse sections taken from various Nissl series of cat's semilunar ganglia. In general, the chromatolytic cells appear as circles and the normal cells are shown in solid black. All cells were first outlined with the aid of a camera lucida. (See footnote 1, p. 9.)

ABBREVIATIONS

A-B, projection line
Alv.I.C., nervus alveolaris inferior cells
Lin.C., nervus lingualis cells
Man.C., nervus mandibularis cells
Man.F., nervus mandibularis fibers
Max.C., nervus maxillaris cells
Max.F., nervus maxillaris fibers
Max.Opth.C., nervus maxillaris and n. ophthalmicus cells
N.Man., nervus mandibularis
N.Man.S., sensory portion of the nervus mandibularis
N.Max., nervus maxillaris
N.Opth., nervus ophthalmicus
Opth.C., nervus ophthalmicus cells
Opth.F., nervus ophthalmicus fibers
R.Ant.V., radix anterior n. trigemini (portio minor or motor root)
R.Post.V., radix posterior n. trigemini (portio major or sensory root)
VI, nervus abducens

MICROSCOPICAL STUDY

It is obvious from the two reconstructions of series 203 (figs. 1 and 2) that the cells of the ganglion semilunare of the cat occupy a much larger area than the narrow ridge of gray matter shown in gross preparations of this ganglion. Also it is apparent that the ganglion assumes more or less the form of a right-angled triangle, having its apex directed cephalo-median and its base caudo-lateral. The motor and sensory roots (*R.Ant.V.* and *R.Post.V.*) leave the hypotenuse side, the former crossing the ventral surface of the ganglion from the region of the right angle to the center of the hypotenuse. The nervus ophthalmicus (*N.Opth.*) enters the apex from in front and medially, the nervus maxillaris (*N.Max.*) the opposite side from the hypotenuse, and the nervus mandibularis (*N.Man.*) the base from the side and in front.

1. Ophthalmic-maxillary and mandibular ganglia

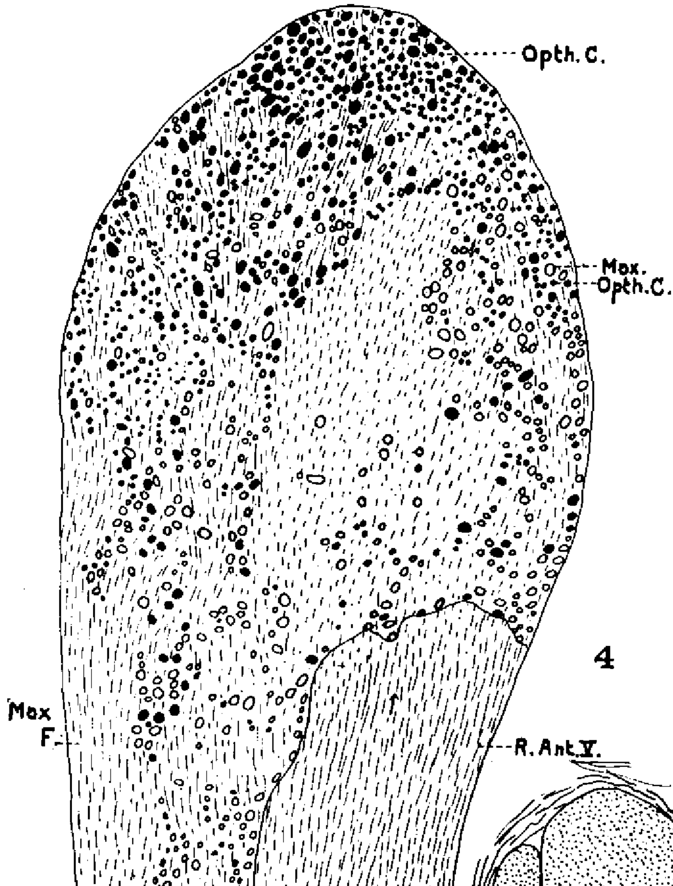
Figures 1 and 2 demonstrate that the ganglion semilunare of the cat is sharply divided into two portions or ganglia. A cephalic-median area, blocked in by parallel lines and occupying about two-thirds or more of the ganglion, represents the ophthalmic-maxillary division or ganglia. The stippled area situated caudally and laterally, marks the nervus mandibularis area or ganglia (*Man.C.*) For the most part these two divisions or ganglia do not come in contact with each other, but for a short distance where the most lateral and caudal of the trigeminal motor root fibers are crossing the ganglia and for a short distance caudally and laterally they overlap. At this point the mandibular cells lie ventrally to the ophthalmic-maxillary cells. This is shown in figure 1 where the heavy broken line indicates the cephalic and median border of the nervus mandibularis cells.

Ophthalmic-maxillary ganglion. A section through the cephalic end of the ganglion semilunare immediately before the nervus ophthalmicus is received and some distance cephalad of the entrance of the n. mandibularis is shown in figure 3.[1] All of the cells in this figure and in the following figures of transverse sections were outlined with the aid of a camera lucida. If normal they were drawn in solid black, but if chromatolytic they were left in outline. It is obvious that practically all of the cells of this section are chromatolytic and consequently are n. maxillaris cells (*Max.C.*). The few that are normal may be cells of maxillary fibers that entered the nerve centrally to the lesion. It is also possible that some of the normal cells in the upper part of the section may be ophthalmic cells, since this nerve enters the ganglion in this region a few sections farther on. However, it should be mentioned that Nissl series 208 in which the n. ophthalmicus was severed discloses no chromatolytic cells cephalad of the entrance of the ophthalmic fibers, and more cephalic sections than figure 3, in series 203, demonstrate almost no normal cells. This area of chromatolytic cells immediately in front of the entrance of the ophthalmic nerve at the base of the n. maxillaris in series 203 is then an area composed exclusively of maxillary cells. It is represented by horizontal shading (*Max.C.*) in the reconstructions (figs. 1 and 2).

One normal cell is present in the n. ophthalmicus in the section from which figure 3 was drawn. This and another cell are shown in the ophthalmic nerve in figures 1 and 2 as dots. Two chromatolytic cells likewise appear as dots in the maxillary nerve in figures 1 and 2. Also there were several small pale cells in these nerve sheaths which are suggestive of round wandering cells.

Figure 4 is a section from Nissl series 203 (n. maxillaris cut) through the cephalic end of the maxillary-ophthalmic division of the ganglion semilunare at the level where the motor root, radix anterior n. trigemini (*R.Ant.V.*), is beginning to cross the ventral surface of the ganglion and a few sections behind the entrance of the last of the n. ophthalmicus fibers. It is clear from this figure that the apex cells are

[1] In each of the figures of transverse sections (figs. 3 to 10) the upper border represents the inner surface of the ganglion semilunare; the lower border, the lateral surface of the ganglion; the right border, the ventral surface of the ganglion and the left border, the dorsal surface of the ganglion.



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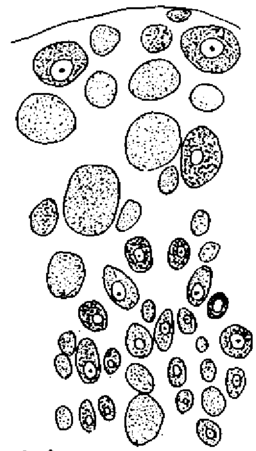
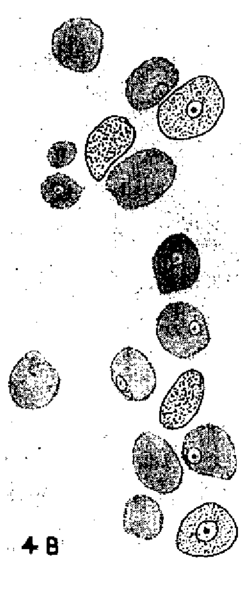


4 A



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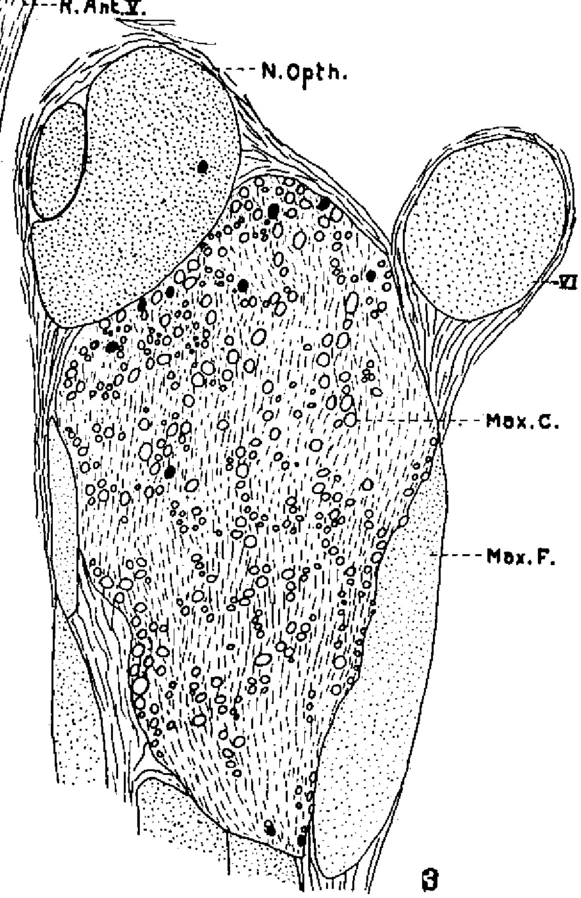

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normal ophthalmic cells (*Opth.C.*), since they are from the median side of the ganglion or the same side that the n. ophthalmicus entered the ganglion a few sections cephalad. Below this area in the section, laterally in the ganglion, the cells are a mixture of chromatolytic maxillary and normal ophthalmic cells (*Max.Opth.C.*). It should be recorded in connection with the ophthalmic area at the apex in figure 4, and in figure 4 A, a more highly magnified strip of cells from this area, that a large number of these normal ophthalmic cells belong apparently to the small non-medullated cells of Cajal and Dogiel's descriptions. In the maxillary-ophthalmic area of figure 4 it is obvious that the chromatolytic maxillary cells are more numerous than the normal ophthalmic, and that the latter, which are more or less in clusters, appear to be migrating downward in the section, laterally in the ganglion. Nissl series 207, in which the nervus alveolaris inferior, n. lingualis and n. mylohyoideus had been cut, demonstrates that no chromatolytic n. mandibularis cells extend cephalad of the entrance of the sensory fibers of this nerve in the ganglion (figs. 9, 9 A). Consequently, none of the normal cells in figure 4, which is some distance cephalad of figure 9, could be mandibular cells. Figure 4 B is similar to 4 A, but taken from the center of the maxillary-ophthalmic area of the same section as figure 4 and drawn with sufficient magnification to portray cell structure. A similar section to figure 4 from Nissl series 208 where the n. ophthalmicus had

Fig. 3 Transverse section through the cephalic end of the ganglion semilunare or maxillary area of the same series as figures 1 and 2. This section is taken a few sections before the entrance of the n. ophthalmicus fibers. Leitz Apo. 16-mm. obj. and per. oc. 6x. × 23⅓.

Fig. 4 A more caudal section than figure 3 from the same series, taken immediately after the entrance of the n. ophthalmicus fibers and before any of the sensory n. mandibularis fibers have been received. Leitz Apo. 16-mm. obj. and per. oc. 6x. × 23⅓.

Fig. 4 A More highly magnified portion of a few cells from the median or ophthalmic portion of the same section as figure 4. Leitz Apo. 4-mm. obj. and per. oc. 6x. × 93⅓.

Fig. 4 B Same as 4 A, but from the center or maxillary-ophthalmic portion of the same section as figure 4. × 93⅓.

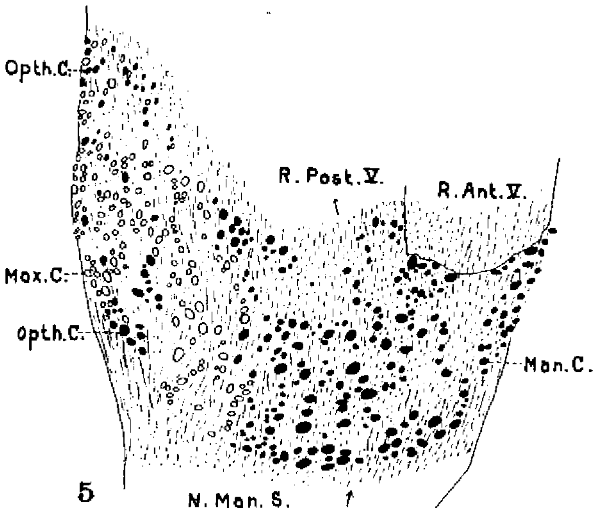
been severed presents an identical picture, except that the ophthalmic cells are chromatolytic.

More caudal sections of series 203 and 208 and reconstruction figures 1 and 2 reveal the area of ophthalmic cells to extend but a short distance laterally and caudally. In the reconstructions this area is shown by the vertical-line shading (*Opth.C.*) It should be stated, however, that both series 203 and 208 disclose the ophthalmic cells predominating over the maxillary cells medially, that is, dorsally in the sections throughout the entire length of the maxillary-ophthalmic division of the ganglion semilunare. It is also clear from more caudal sections of series 203 and 208 and from the reconstructions (figs. 1 and 2) that the maxillary-ophthalmic area or ganglion, represented by both vertical- and horizontal-line shading, stops caudally in figure 1 where this type of shading stops, and in the ventral reconstruction (fig. 2) it ends with the heavy broken line designated by *Max.-Ophth.C.* This is a little caudal to the crossing of the last fibers of the motor root (fig. 2, *R.Ant.V.*).

It is obvious from figures 1 and 2 that for a short distance the caudal end of the ophthalmic-maxillary portion of the ganglion semilunare overlaps the mandibular division of the ganglion. Wherever this overlapping occurs the mandibular division is always ventral to the ophthalmic-maxillary division. It will be seen from the following paragraphs that there is little, if any, mixing of these two portions of the ganglion semilunare. In other words, there are two distinct ganglia, an ophthalmic-maxillary ganglion and a mandibular ganglion.

Region of overlapping. A typical transverse section through that part of the ganglion semilunare where the ophthalmic-maxillary ganglion overlaps the mandibular ganglion in series 203 (maxillary nerve severed) is shown in figure 5. In this figure[2] the mass of normal cells to the right, ventral half of the semilunar ganglion, is the mandibular ganglion or the mandibular division of the ganglion

[2] In connection with figure 5 and following figures 6 to 10, see footnote 1, page 9.



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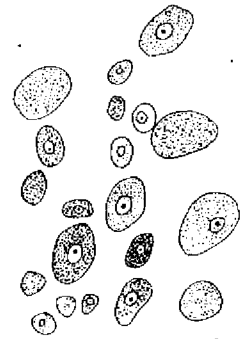

5 A

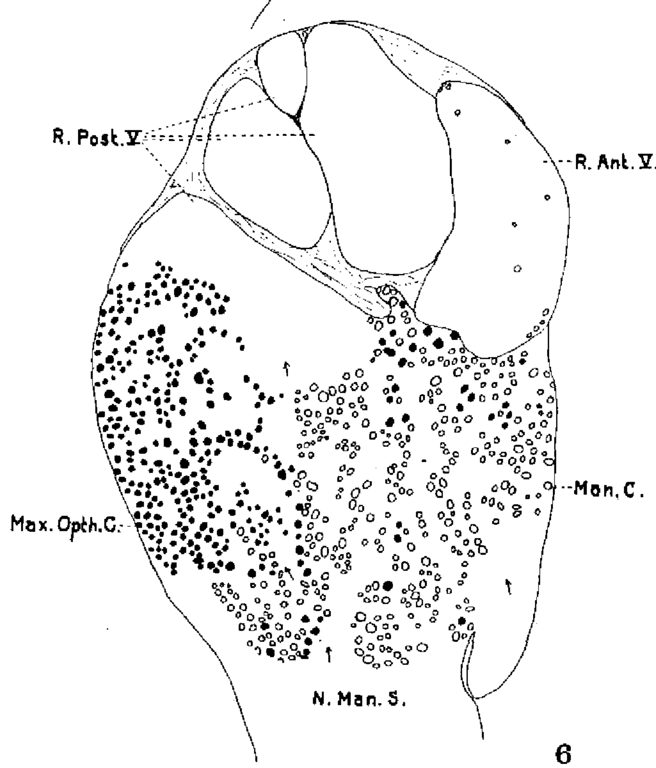

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Fig. 5 Transverse section from the caudal third of the same series as figures 1 to 4 (no. 203, maxillary nerve cut in orbit). This section passes through that part of the semilunar ganglion where the maxillary-ophthalmic ganglion, to the left in the section, overlaps the normal mandibular ganglion to the right. Leitz Apo. 16-mm. obj. and per. oc. 6x. × 23⅓.

Fig. 5 A Typical area from the fifth section from the caudal end of the ganglion semilunare of the same series as figures 1 to 5. This section is through the mandibular ganglion and discloses only normal cells. Leitz Apo. 4-mm. obj. and per. oc. 6x. × 93⅓.

Fig. 6 Transverse section from about the same level as figure 5, but from Nissl series 207 where the n. alveolaris inferior, n. lingualis and n. mylohyoideus were cut. In this section the normal maxillary-ophthalmic ganglion is to the left and the chromatolytic mandibular ganglion is to the right. Leitz obj. 2 and oc. 3. × 15⅓.

semilunare (*Man.C.*). To the left of the section the maxillary-ophthalmic ganglion or maxillary-ophthalmic division of the ganglion semilunare is composed of chromatolytic maxillary cells (*Max.C.*) and normal ophthalmic cells (*Opth.C.*). As stated previously, the normal ophthalmic cells are more abundant in the upper part of the section, medially in the ganglion, and the chromatolytic maxillary cells are more numerous elsewhere in the ganglion. Ordinarily, as shown in figure 5, these two ganglia are not separated by a bundle of nerve fibers or connective tissue; there is, notwithstanding, a sharp line of demarcation between their respective cells. This line of separation may sometimes be slightly wavy or zigzag. Some sections may show one or more chromatolytic cells in the normal ganglion area, but when this occurs they are usually close to the border-line. It is also possible that some of these chromatolytic cells may be accounted for by the fact that any normal area may have a cell undergoing decomposition. A section at the same level from series 208 (nervus ophthalmicus cut) was drawn for comparison with figure 5, but it was not included as a figure for the reason that it differed from figure 5 only in having its normal and chromatolytic cells reversed.

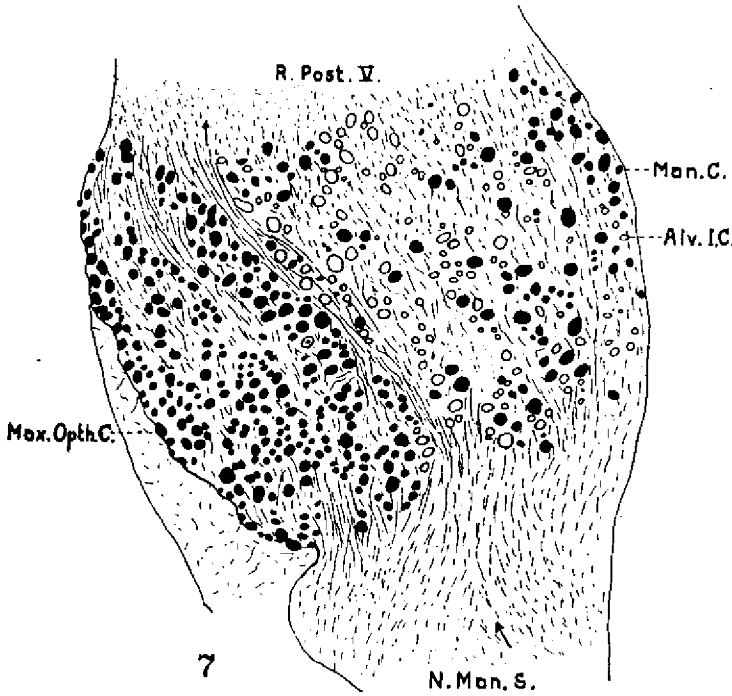
In figure 6 we have a section from Nissl series 207 from the same region as figure 5, but cut at a slightly different angle. In this series the nervus alveolaris inferior, n. lingualis, and n. mylohyoideus were severed. This figure reveals the mandibular ganglion cells (*Man.C.*) to the right or ventral to the maxillary-ophthalmic cells (*Man.Opth.C.*). The maxillary-ophthalmic ganglion occupies identically the same position in this section that it did in figure 5, but in this section and series its cells are all normal; while the cells of the mandibular ganglion are for the most part chromatolytic, the normal ones doubtless representing axones that entered the n. mandibularis centrally to the lesion. The section from which figure 6 was drawn is situated near the caudal end of the maxillary-ophthalmic ganglion at the point where this ganglion is rapidly being encroached on by the mandibular ganglion. In the lower part of the section the arrows indicate a number of mandibular fibers invading the territory of the maxillary-ophthalmic ganglion, a few of these cells persist at the level of this section, but in the following section they are all mandibular cells. This and similar areas then simply represent a more or less oblique or longitudinal cut through the line of division between these two ganglia, which is not to be interpreted as an intermingling of the cells of these two distinct ganglia. Sections taken from practically the same area from Nissl series 196, where the n. alveolaris inferior was cut, and Nissl series 197, where the n. lingualis was severed, exhibit practically the same pictures (figs. 7 and 8) as figure 5, except that they possess a lesser number of chromatolytic cells in the mandibular ganglion. In both figures, with one exception in figure 7, the chromatolytic cells are confined solely to the mandibular area or ganglion. This cell while in the normal maxillary-ophthalmic area is close to the border-line. Furtherfore, it can be stated that a number of duplicate series in which one or a part of one of the three afferent trigeminal nerves were cut confirm the existence of a complete separation of these two ganglia of the semilunare.

Caudal portion of the mandibular ganglion. Figures 1 and 2 demonstrate that about two-thirds of the mandibular ganglion is situated caudad and laterad of the ophthalmic-maxillary ganglion. It is this part of the ganglion semilunare that is partly overarched by the tympanic bulla. Figure 5 A or any other section from series 203 in which the n. maxillaris was cut discloses only normal cells in this area. On the contrary, any section through this region in series 207 (n. alveolaris inferior, n. lingualis, and n. mylohyoideus cut), as, for example, figures 10 and 10 A, shows this area of the mandibular ganglion to be composed almost entirely of chromatolytic mandibular cells (*Man.C.*). The few normal cells present undoubtedly possess axones that entered the n. mandibularis centrally to the lesions. Similar sections from series 196 and 197 (figs. 7 and 8) in which the n. alveolaris inferior and the n. lingualis were severed, respectively, reveal chromatolytic cells scattered through this portion of the mandibular ganglion and exhibit no definite area of normal cells.

Localization in the mandibular ganglion. An examination of the sections throughout the mandibular ganglion in series 196 where the n. alveolaris inferior was severed demonstrates at least half of the cells to be in a state of chromatolysis (fig. 7, *Alv.I.C.*). The remaining normal cells (*Man.C.*) must be either n. lingualis cells or cells whose axones entered the n. mandibularis centrally to the lesion. In the extreme caudal sections of series 196 the cells are predominantly n. alveolaris inferior cells. Of the 132 cells in the fifth from the last section, all but seven or eight are chromatolytic. A study of the cells in series 197, in which the n. lingualis was cut, likewise proves that there is no definite area in the mandibular ganglion for n. lingualis cells. In most sections, as in figure 8, the lingual cells (*Lin.C.*) are scattered uniformly throughout the section, usually in small groups. They constitute about one-third of the cells of a section. Although present in the extreme caudal sections, they are reduced considerably in number. In the fifth from the last section of series 197, only three out of ninety-eight cells are chromatolytic lingual cells.

2. Nerve cells outside the ganglion semilunare

Attention has been directed previously to a few isolated nerve cells in the nervus ophthalmicus and in the n. maxillaris in figures 1 and 2. Similar cells are also present in these nerves in all my Nissl series. A few isolated cells are likewise visible in the n. mandibularis and in the sensory root (fig. 1, *R.Post.V.*). In connection with the motor root, radix anterior n. trigemini (fig. 2, *R.Ant.V.*) there are numerous small cells in and about the root as it crosses the ventral surface of the ganglion and for a short distance centrally to its crossing. They appear singly and in clusters of from three to a dozen cells. Some of the smaller oval cells with a gen-



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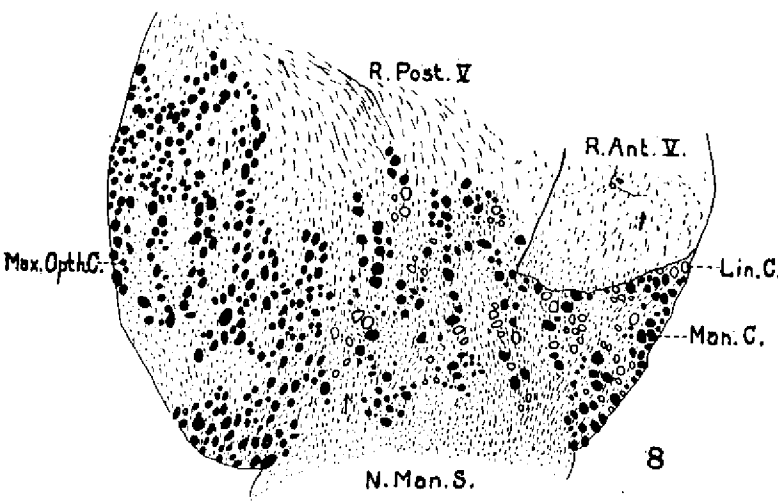

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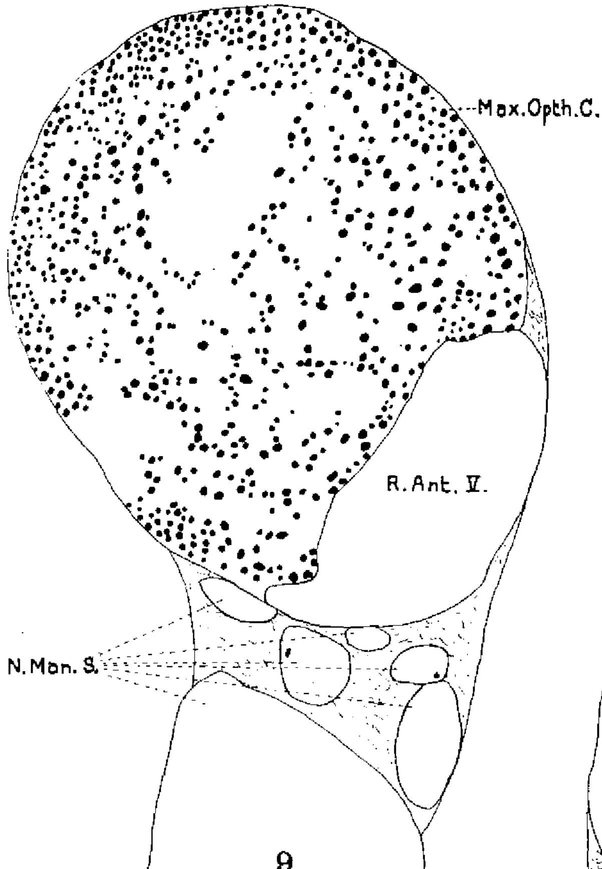
Fig. 7 Similar transverse section to figures 5 and 6, but from Nissl series 196 where the n. alveolaris inferior was cut. As in the above figures the mandibular ganglion is to the right of the section and the maxillary-ophthalmic to the left. Leitz Apo. 16-mm. obj. and per. oc. 6x. $\times 23\frac{1}{3}$.

Fig. 8 Similar section to figures 5 to 7, but from Nissl series 197 where the n. lingualis was severed. As in the previous figures the mandibular ganglion is to the right and the maxillary-ophthalmic ganglion is to the left. Leitz Apo. 16-mm. obj. and per. oc. 6x. $\times 23\frac{1}{3}$.

erally clear cytoplasm may be round wandering cells. They are suggestive of the plasma cells described by Mayer in 1906 for the semilunar ganglion of man, and recall McKibben's later description of clasmatocytes in the olfactory nerve, nasal capsule, and meninges of Necturus. The Cajal series portray some of these cells with typical coiled processes of the spinal ganglion type. The Nissl series show many of them to be chromatolytic and all of the series reveal capsules surrounding most of these cells. So that the present indication is that the majority of the cells in and about the motor root are nerve cells. So many complications have arisen in connection with these cells that the writer expects to take them up in more detail in a later paper.

It can be stated provisionally that many of these cells situated between the motor and sensory roots and between the motor root and the capsule are apparently ophthalmic-maxillary and mandibular ganglion cells that have migrated centrally along the path of the motor root. The dozen cells in the motor root (*R.Ant.V.*) in figure 6 appear to be chromatolytic. After taking into consideration that in this series the n. mylohyoideus was severed in common with the n. alveolaris inferior and the n. lingualis, together with the additional observations recorded in a previous paper on the mesencephalic trigeminal root, namely, that destruction of the ganglion semilunare produces ascending Wallerian degeneration in the mesencephalic root, and that cutting the mesencepalic root in the pons causes degeneration of the fibers in the motor nerves supplying the masseter and temporal muscles, but none in the n. mandibularis supplying the mylohyoideus and digastric muscles, it is certainly suggestive that some of the cells in the motor root approximating the ganglion may be proprioceptive cells originating from the mylohyoideus and digastric muscles. To establish this point, a Nissl series in which the n. mylohyoideus has been severed without injuring the other nerves is necessary, and such an experiment is in progress.



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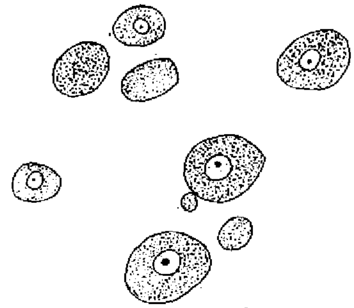

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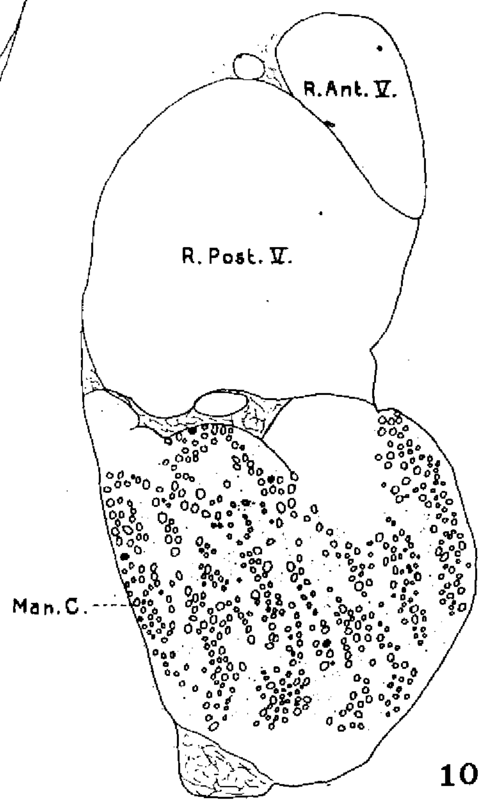

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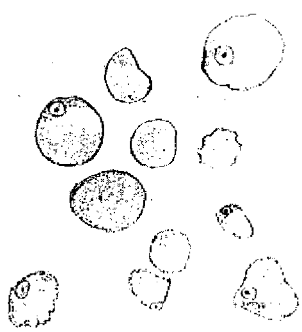

10 A

Fig. 9 Transverse section from Nissl series 207 where the n. alveolaris inferior, n. lingualis, and n. mylohyoideus had been severed. It is from the same series as figure 6, but at a lower level where the motor root, radix anterior V, is crossing the ganglion and cephalad to the entrance of any of the sensory n. mandibularis fibers. Leitz obj. 2 and oc. 3. × 15⅓.

Fig. 9 A A few typical normal cells from the same section as figure 9 more highly magnified to show cell structure. Leitz Apo. 4-mm. obj. and per. oc. 6x. × 93⅓.

Fig. 10 More caudal transverse section through the mandibular ganglion of the same series as figures 6 and 9. This section is below the level of the entrance of the sensory n. mandibularis fibers and the 65 section of 15 μ from the end of the ganglion. Leitz obj. 2 and oc. 3. × 15⅓.

Fig. 10 A A group of typical chromatolytic cells from the same section as figure 10, but more highly magnified and accurately drawn. Leitz Apo. 4-mm. obj. and per. oc. 6x. × 93⅓.

In this connection the previous work on the ganglion cells in the eye muscle nerves is of interest. Many years ago, Thomsen and Gaskell described peculiar patches in the eye muscle nerves which they took to be altered nerve cells or degenerated ganglia. Tozer, in 1912, observed typical nerve cells in the eye muscle nerves of monkeys, pigeons, and a fish. They were said to be mainly in the connective tissue outside the nerve. In the III nerve of one monkey seventy-four cells were counted. Also he found that these cells degenerated in monkeys after severing the nerve peripherally. More recently, Nicholls described as many as fifty-odd cells in the III nerve of the shark, Scyllium, situated in the nerve intracranially, and since the above was written Miss Nicholson has described ganglion cells in the third and sixth nerves in man.

SUMMARY AND CONCLUSIONS

1. A reconstruction of the ganglion semilunare of the cat demonstrates that it occupies a much larger area than the elevated ridge exhibited in gross preparations. In general it has the shape of a right-angled triangle, having its apex directed medially and its base laterally. The sensory and motor roots leave from the caudo-medial or hypotenuse side, the latter crossing the ventral surface of the ganglion rather obliquely. The nervus ophthalmicus enters the apex of the triangle from in front, the n. maxillaris the side opposite the hypotenuse from in front, and the n. mandibularis the base, from the side and in front.

2. The Nissl series in which the n. maxillaris had been severed and all of the Nissl series in which one or a branch of one of the three trigeminal nerves had been cut demonstrate that there are two separate and distinct ganglia in the ganglion semilunare of the cat. A large cephalic and median portion, shown by parallel-line shading in figure 1, consists only of ophthalmic-maxillary cells. A smaller lateral and caudal division, stippled in figure 1, is made up entirely of mandibular cells. The latter is partly overarched by the wall of the temporal bulla.

3. Dorsally about three-fourths of the entire ganglion semilunare is ophthalmic-maxillary ganglion and about one-fourth mandibular ganglion, while ventrally the ratio is about two-thirds to one-third. The region of overlapping includes a small area where the last motor fibers are crossing the ganglion and an adjoining area of about equal size immediately caudal and lateral to the crossing of motor root fibers (figs. 1 and 2).

4. Every Nissl series in which one of the three trigeminal nerves or branch of the same was cut reveals no mixing of the cells of these two ganglia at the point of their overlapping.

5. In the ophthalmic-maxillary ganglion both reconstructions exhibit: *a*) A narrow strip of purely maxillary cells, cephalically, at the base of the n. maxillaris. *b*) A small area of ophthalmic cells, cephalically and medially, at the base of the n. ophthalmicus. *c*) A mixture of both nerve cells throughout the rest of the ganglion; the ophthalmic cells predominating near the median border, and the maxillary, elsewhere.

6. A large number of ophthalmic cells at the base of the ophthalmic nerve are small cells, belonging apparently to the small non-medullated type of Cajal and Dogiel's descriptions.

7. There is no definite localization of the n. alveolaris inferior and n. lingualis cells in the mandibular ganglion. Cells from each of these nerves, usually somewhat bunched, are scattered throughout the entire ganglion; however, it was noted that the n. alveolaris inferior cells are much more numerous in the extreme caudal and lateral end of this ganglion.

8. There are a few isolated nerve cells in the n. ophthalmicus, n. maxillaris, n. mandibularis, and in the sensory root in close proximity to the ganglion. A number of isolated and small groups of cells appear in the motor root and immediately outside, in the region where the root is crossing the ganglion and centrally. Present indications are that most of these cells are nerve cells, but some of the smaller paler ones resemble the round wandering cells, recalling the plasma

cells of Mayer's description. Apparently some of the cells outside of the root are ophthalmic-maxillary and mandibular ganglion cells that have migrated centrally along the path of the motor root. Some of the cells within the motor root may be proprioceptive cells having their peripheral processes supplying the mylohyoideus and digastric muscles(?).

CLINICAL APPLICATION

If there is the same localization in the human ganglion semilunare as there is in the cat's ganglion, and there is every reason to believe that this is the case, it is probable, in cases of trifacial neuralgia involving the nervus mandibularis, that the mandibular division of the ganglion could be destroyed without injuring the ophthalmic-maxillary portion or its afferent and efferent fibers or the motor root. Thereby removing the pain permanently without destroying the eyelid reflex, which, if destroyed, causes ultimate blindness to the eye on the lesion side.

If a comparison is made between my figure 1 and Spalteholz's figure 761 and my figure 2 and Spalteholz's figure 762 or a copy of the same, my figure 11, the similarity is obvious. The writer is of the opinion that the area shown in black in figure 11 probably contains all of the mandibular cells in the human ganglion semilunare. If so, this area can doubtless be destroyed without damaging the ophthalmic-maxillary ganglion cells sufficiently to block the eyelid reflex. To accomplish this, several methods suggest themselves. All that should be necessary would be to cut the central processes of the mandibular cells (fig. 11, *Man.C.*) close to the ganglion beginning at the point where the first motor fibers are crossing the ganglion and continuing in a caudo-lateral direction. The entire mandibular ganglion could be burned out with an electric cautery (the cautery should have a platinum ball tip about the size or a little smaller than the area of the mandibular ganglia), or this ganglion can be destroyed through rotation of a chisel possessing a blade equal in width to the diameter of the ganglion. Also the mandibular ganglion might be destroyed through injection of alcohol or some other fluid. In any method used, care should be exercised not to injure the ophthalmic-maxillary ganglion (fig. 11, *Max. Opth.C.*), its afferent or efferent fibers, or the motor root. Also nothing should be done that would later affect these areas.

It is even possible that there are sufficient ophthalmic cells at the base of the ophthalmic nerve (*Opth.C.*) to preserve the eyelid reflex. So that in trifacial neuralgia involving the maxillary nerve or both the maxillary and mandibular nerves it might be possible to destroy all of the ganglion semilunare but this area. The danger in this operation would come from cutting the central processes of all the ophthalmic cells.

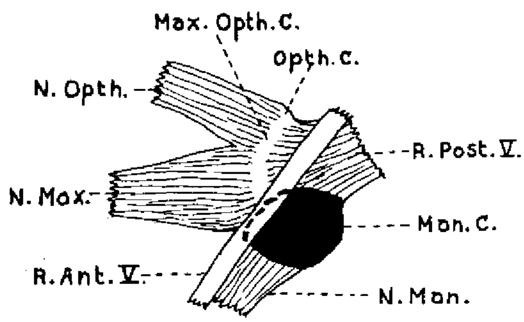

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Fig. 11 Tracing from Spalteholz's figure 762 of the human ganglion semilunare as seen from the ventral side. The area that the writer believes to be the mandibular ganglion is shown in black.

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