THE NEUROHISTOLOGY OF THE CAROTICOTYMPANIC REGION AND RELATED CRANIAL NERVES

by

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This work is done in order to formulate a histological basis for the understanding of the complex anatomy of the region of the carotid plexus, tympanic plexus, and related cranial nerves. The serial section method with human material using the Muller modification of the Weigert stain has been employed. A brief review of the comparative anatomy and gross anatomy of the region is given to demonstrate the present status of knowledge in this field and to justify the terminology used.

A microscopic study reveals that fine myelinated and unmyelinated fibers pass from the superior cervical ganglion into its branches of distribution along the carotid artery and into its branch of communication with the glossopharyngeus. The fine myelinated fibers pass up the carotid, while the unmyelinated pass into the great deep petrosal as well as up the carotid artery. The great superficial petrosal consists of small myelinated fibers which synapse in the sphenopalatine ganglion, and of lrage myelinated fibers which pass through this ganglion. In the mid-portion of the Vidian nerve gang-

lion cells are found in both portions, and a bundle of unmyelinated fibers passes from the great deep into the great superficial petrosal portion. The unmyelinated fibers of the great deep petrosal pass through the sphenopalatine ganglion into its branches of distribution and into the maxillary nerve. A small bundle of large and medium-sized myelinated fibers pass from the Vidian nerve, the great deep petrosal, and into the carotid plexus toward the superior cervical ganglion.

The communicating filament between the glossopharyngeus and vagus consists of large myelinated fibers which split, one bundle running toward the jugular, and the other into the nodose ganglion. The vagus consists of varying sized myelinated and unmyelinated fibers which assemble below the jugular ganglion and break up into fascicles as the nodose ganglion is reached; most of the large myelinated fibers pass off into the nerves of distribution of the ganglion. The bulbar accessory consists of large myelinated fibers. The glossopharyngeus is similar to the vagus in structure.

The nerve of Jacobson consists of medium-sized myelinated fibers which arise from the petrous ganglion; these fibers pass directly into the lesser deep petrosal and common caroticotympanic nerves. The communicating filament between the lesser superficial petrosal nerve and geniculate ganglion is made up of scattered small myelinated fibers; that between the nerve of Jacobson and the superior caroticotympanic consists of small and medium-sized myelinated fibers.

Ganglion cells are found on the nerve of Jacobson at the point where the branch running toward the vagus joins, on the lesser superficial petrosal at its junction with its branch of communication with geniculate ganglion, and on the superior caroticotympanic at its junction with the filament from the nerve of Jacobson. The fibers of the superior caroticotympanic cannot be traced beyond the carotid artery; those of the inferior caroticotympanic are distrituted along blood vessels below the jugular foramen.

The thesis is concluded with a brief discussion of the possible explanations of referred pain in nasopharyngeal infection on the basis of the neuroanatomy of the part.

INTRODUCTION

A brief study of the various descriptions of the region of the sphenopalatine ganglion, the carotid and tympanic plexuses, and related nerves manifests the fact that it is not well understood. Vague references to fiber tract connections between the cranial nerves involved are numerous, and discrepancies in the account of certain of the gross connecting filaments are found. The comparative anatomy of this region has been fairly well worked out, and the gross description, in the main, is fairly adequate, but many of the essential details are referred to in an indefinite manner or represented by inexact diagrams. The terminology is confusing in many cases, and conclusions have been formed which more complete evidence shows to be in need of modification.

A perusual of the literature on this subject points to a lack of microscopic studies, this being especially true of the tympanic region and its connections. Fiber tracts are not described in this area; one or two references are made to scattered nerve cells in this region, and the intrinsic nerve supply of the various organs has been studied, but the relationship between these seems to have been left to conjecture. Before one is able to apply experimental methods by nerve degeneration and chromatolysis, it is essential to know the neurohistology of the part in order to be able to identify the cells and fiber tracts.

In the following account the main emphasis will be laid upon the microscopic structure of the various nerves describ-ed, but a preliminary review of the comparative anatomy of the region and a study of the gross structures in the human should first be considered.

COMPARATIVE ANATOMY

As a starting point in consideration of the comparative anatomy of this region, elasmobranch fishes may be considered. In these organisms the typical cranial nerve has a rostrally directed or palatine branch, and a pretrematic and post-trematic branch on either side of the gill-slit. In the trigeminal or fifth nerve these branches become the ophthalmic (rostral), maxillary (pretrematic to the mouth cleft), and mandibular (post-trematic). In the facial or seventh nerve this representation is found in the palatine, the internal mandibular and hyomandibular. This same plan of structure is seen in the glossopharyngeal or ninth nerve and in all the rootlets of the vagus or tenth except the fourth rootlet which is directed caudally as the intestinal branch.

In the process of cephalogensis these nerves undergo differentiation and the identity of the early metameric divisions becomes distorted. In accordance with adaptation to function and as a result of phylogenetic changes, both the functional components and morphology of the cranial nerves undergo modification; thus the primary functional components of the cranial nerves in some cases become large and important and in other vestigial.

In 1899 Francis Dixon demonstrated that the facial nerve had a sensory distribution instead of being a purely motor nerve as had been previously supposed. This conclusion was based on the phylogeny of the intermediate nerve.

One branch of the intermediate was directed rostrally as the palatine branch of the facial and another was directed into the hyomandibular branch. The former or palatine seventh contained sensory fibers to the mucous membranes of the naso-pharynx and remains as a visceral sensory component existing in later forms as the great superficial petrosal nerve. The latter has existed as a somatic sensory branch supplying the hyoid region; it has been demonstrated in the mouse by Rhinehart (1918), and in the human by Larsell and Fenton in 1928. This nerve in man anastomoses with a somatic sensory branch of the vagus to form the nerve of Arnold which innervates the skin of part of the posterior portion of the external ear, tip of the mastoid and possibly the tympanic membrane. The internal mandibular, also a branch of the nervus intermedius, contained special visceral sensory fibers to the taste buds and has become the chorda tympani.

In the glossopharyngeus a nerve modification has also occurred. The palatine branch has become incorporated with the palatine seventh and forms an anastomosis with the geniculate ganglion of the facial nerve; this persists as the nerve of Jacobson and is probably a visceral sensory component. The origin of the lesser superficial petrosal is somewhat in doubt, although it seems to be an integral part of the nerve of Jacobson.

The rootlets of the vagus nerve have become crowded together possibly with cells of the glossopharyngeus and bulbar accessory nerve, thus accounting for the anastomoses between the main ganglia of these nerve in man. The original metameric identity is lost in the development of the larynx and pharynx which the vagus supplies; the intestinal branch is easily identified in man.

With the migration of cells from the neural crest and its resulting cerebrospinal ganglia, sympathetic ganglia take their formation. The sphenopalatine ganglion is such a sympathetic ganglion formed by the migration of cells from the gasserian ganglion of the trigeminal, and receiving fibers (and possibly a few cells) from the geniculate ganglion of the facial (as shown by Kuntz in the pig- 1913). Wilder looks upon the great and lesser deep petrosal as a continuous nerve which originates as a branch of the nerve of Jacobson and goes to the sphenopalatine ganglion. However, we shall subsequently show that in man the picture is not so simple as depicted by Wilder.

METHOD OF INVESTIGATION

Specimens were taken from fresh autopsy material which included the region at the base of the skull between the sphenopalatine ganglion anteriorly and the jugular foramen posteriorly and extending as far as the angle of the mandible inferiorly. The specimens were placed immediately in ten percent (10%) formalin and allowed to fix for two months. The formalin solution was changed on an average of once a week. The mastoid air cells and middle ear cavity were opened to permit the penetration of the formalin into the bone.

The tissue was then prepared for dissection by being soaked overnight in running water. Bone forceps, teasing needles, small toothed and plain forceps, and seekers were the instruments used. The various structures were identified by their relationships and by their gross morphology. Spalteholz' and Toldt's anatomy texts were used as guides in identification of the structure. The finer dissection was carried out under the binocular dissecting scope. Care was taken to chip the bone away little by little to prevent injury to the intra-osseous nerves. After each session of dissection the tissues were placed in five percent (5%) formalin, and care was taken to keep the tissues moist during the active dissection.

When the nerves and all their connections were exposed, they were spread apart as much as could be permitted in order to keep the nerve fibers in as near the same plane as possible and in order that their identification would be simpler in the sections. The specimen was then fastened to cardboard by means of thumbtacks placed in the portions of the material which were not to be retained; a drawing was made of the praparation and the anatomical parts were labelled.

The staining technique as outlined in the Müller modification of the Weigert stain for myelin was employed. The whole preparation was placed in the first mordant which consisted of:

Potassium bichromate	5 parts
Chromium fluoride	2.5 parts
Distilled water	100 parts,

and was placed in an incubator at 35° C for three days. It was then washed and transferred to seventy percent (70%) alcohol which was changed every day until the alcohol ceased to be discolored.

The preparation was then passed up through graded alcohol solutions (viz; 80%, 95%, and absolute alcohol) and then placed overnight in oil of cedarwood. After clearing, the preparation was placed in xylol until the oil of cedarwood was removed and then in 48° C paraffin in an incubator for two hours. This step was repeated until the odor of xylol could no longer be detected in the preparation. Following this it was placed in one-third 58° C paraffin and two-thirds 48° C paraffin for two hours, and then for the same length of time in two-thirds 58° C paraffin and one-third 48° C paraffin. The preparation, while still in the warmed paraffin mixture was cut into appropriately sized blocks, and each block was placed in two-thirds 58°C paraffin and one-third 48°C paraffin (at 70°C to expel the air) and allowed to harden overnight in cold water. The blocks were then numbered and marked to indicate their proper relationship with each other, and then the blocks were correspondingly marked off on the drawing.

Each block was set in a sliding microtome object holder in the position which it bore in the original preparation, and sections were made at sixty microns (60μ) in thickness and were transposed in series to glass slides. The sections were made adherent to the slides by the use of egg albumin and by being placed on a plate at 37°C until they lay smooth on the slide. The slides were numbered in order and then placed in carriers and transferred to xylol until the paraffin had dissolved and thence to albolute alcohol and then dipped in one percent (1%) celloidin (in equal parts of alcohol and ether) in order to form a thin protective sheet over the slide to prevent the sections floating off in the solutions. They were passed down through graded alcohols and placed for twenty-four hours in the second mordant consisting of:

Chromium fluoride	2 parts
Copper acetate	5 parts
Acetic acid	5 parts
Distilled water	100 parts.

After washing in water, the slides were placed in the staining solution, viz. 0.75% ripened aqueous-alcohol hematoxylin solution, overnight, and then set under running water overnight. The carriers were then placed in the differentiating solution consisting of:

Potassium ferricyanide	2 parts
Borax	2.5 parts
Distilled water	100 parts.

The progress of the differentiating process was followed by removing two or three slides at random from the carrier and observing them under the microscope every few minutes until the desired degree of differentiation was obtained.

The slides were then carried back through the graded alcohol solutions and into xylol. Balsam and cover glasses were mounted on the slides and the balsam was allowed to harden before studying the slides. With this technique the myelinated fibers were stained a dark blue, while the unmyelinated fibers appeared light brown.

The distribution and course of the various fibers were carefully traced under the microscope. The fibers were classified as large medium and small myelinated and as unmyelinated fibers. The ganglia were studied histologically to check the gross identification. The distribution of the fibers were diagrammed, and graphic reconstructions (figures 19 and 20) were made as follows: drawings of each section were made under the Edinger-Leitz projector, and then by superimposing these drawings upon one another with transillumination and tracing the combined picture formed by these superimposed drawings, the fiber tracts were eventually projected onto one plane. The whole picture was thereby presented on one drawing and represented the total work with all the anatomical relationships, as in the original gross drawings, and with a minimum amount of distortion. The finer connections were studied and filled in from microscopic observation. Drawings were then made of the more representative sections with the aid of the camera lucida and the Edinger-Leitz projection apparatus.

DESCRIPTION OF THE GROSS ANATOMY AND RESULTS OF THE GROSS DISSECTION

Having considered the phylogenetic development of this complex region, a basis for an understanding of the gross anatomy in the human has been formed. The description will be confined to the limits studied in this work. The superior cervical sympathetic ganglion lies at the base of the skull just inferior to the jugular foramen. From its superior pole there emerges a large nerve bundle which readily breaks up into three to five smaller branches; these branches pass up along the internal carotid artery and are usually described as forming a plexus about the artery. These small nerves are referred to collectively as the internal carotid nerve. As it nears the foramen lacernum the internal carotid nerve gives off a branch known as the great deep petrosal nerve which joins the great superficial petrosal nerve in the Vidian canal; these two nerves together form the Vidian nerve, and after emerging from the canal, the Vidian nerve enters the sphenopalatine ganglion at its posterior pole. This ganglion lies in the sphenomaxillary fossa and has two communicating branches with the maxillary nerve which lies just superior to it. Gross dissections corroborate the above description.

Lying adjacent to the superior cervical sympathetic ganglion are found the vagus, glossopharyngeal, and accessory cranial nerves which emerge from the base of the skull through the jugular foramen. Various branches of communication between the ganglia of these nerves have been described, but there is a certain degree of individual variation in these connections.

The Japanese worker, Seiichi Schinozaki, has made a very thorough study of the branches of communication between the cervical sympathetics and the vagus in many cases and has compared the right and left side in each case by means of correlation coefficients and finds that there exists a marked degree of individual variation with only a chance relationship between the number of branches on the two sides. In the dissections made in this work there were found in the first case: one communicating branch between the superior cervical ganglion and the glossopharyngeal, and two between the vagus and glossopharyngeal; the accessory nerve joined the vagus at the nodose ganglion. In the second case, owing to the tenacity and abundance of the dura and fibrous connective tissue in the jugular foramen these connections could not be demonstrated grossly for fear of injuring the fine communications and thus spoiling the subsequent microscopic picture.

Passing from the petrous ganglion of the glossopharyngeal nerve the tympanic nerve or nerve of Jacobson was followed. It passes through a special canal in the petrous portion of the temporal bone and enters the cavity of the middle ear at its inferior margin. It is usually described as receiving a branch from the nodose ganglion of the vagus in this canal, but while a branch was found running in this direction, it could not be followed to the vagus. The nerve of Jacobson passes superiorly along the medial wall of the middle ear and near the superior margin it again enters the temporal bone, turns anteriorly near the geniculate ganglion of the facial nerve and runs parallel with and adjacent to the great superficial petrosal nerve. In this latter relationship it becomes known as the lesser superficial petrosal nerve, for it emerges from the temporal bone near the hiatus of the facial canal and runs superficially over its surface to the temporal-sphenoid suture where it again passes through the base of the skull on its course to the otic ganglion. The lesser superficial petrosal nerve was found to have one short communicating branch with the geniculate ganglion and a small, fine connection with the greater superficial petrosal nerve shortly after the latter emerges from the ganglion.

The branches of the nerve of Jacobson in the middle ear cavity seem to have been somewhat hazily understood, and their description is variable in the best of anatomy texts. Since these connections are of importance in the problem under consideration, a brief resume' of the various descriptions is desirable; evidence to justify the terms which are here employed should be presented. The ramifications of the nerve of Jacobson are referred to as the tympanic plexus. In the twenty-second edition of Gray it is described as dividing into branches and ramifying on the promontory to form a plexus; reference is made to a superior and an inferior caroticotympanic nerve between the carotid plexus of the sympathetic and the branches of the nerve of Jacobson and branches of distribution to the mucous membrane of the tympanum (special branches going to the fenestra ovali, fenestra rotundum, and the Eustachian tube). Assertion is also made of "a branch to join the great superficial petrosal nerve". Judging by the diagram as given in Gray (figure 797, 22nd. edition, 1930), it would seem that this branch runs in conjunction with the large deep petrosal nerve.

In Cunningham it is stated that the nerve of Jacobson, after breaking up into branches, forms, along with the caroticotympanic branches of the sympathetic on the internal carotid artery and a twig from the geniculate ganglion, the tympanic plexus. The superior and inferior caroticotympanic nerve together are referred to as the small deep petrosal nerve of the old anatomical terminology.

Piersol, like Cunningham, considers the caroticotympanics and small deep petrosal as synonymous; the small superficial petrosal is described as being formed by a reassembling of the fibers of the plexus. The same branches of distribution are described as by Gray and Cunningham, and, as in Gray, a branch to the great superficial petrosal is described, but definite statement is made that this branch "joins the latter in the hiatus Fallopii". (It, therefore, could not run in conjunction with the great deep petrosal).

In Spalteholz' "Handatlas der Anatomie des Menschen" the course of the main tympanic nerve is described as in the English texts, but the caroticotympanic are described in more detail. The superior caroticotympanic is described as passing to the carotid plexus and sometimes to the great superficial petrosal nerve, while no reference is made to a separate filament of communication between the tympanic plexus and the great superficial petrosal.

In Quain's "Elements of Anatomy" there is found a very convincing description of this region. In the course of the discussion the following statement is made; "The (sphenopalatine) ganglion may also receive fibers from the glossopharyngeal nerve, conveyed to it through the small and large deep petrosal nerves: this connexion is sometimes described as a third sensory root." This fits with the conception advanced by Wilder, i.e.-that the great and lesser deep petroaal are continuous.

(Excellent diagrams of this region are to be found in Spalteholz, 1921, figure 845, vol. III and in Quain,1909, figure 29, vol. III- part 2).

A review of these descriptions makes it difficult to determine exactly what interpretation to apply to the relationship of the nerve of Jacobson to the carotid plexus and petrosal nerves. It is better to employ the terms superior and inferior caroticotympanic nerves than lesser deep petrosal nerve. Inasmuch as the previous descriptions are puzzling (as to whether or not the glossopharyngeal nerve sends fibers to the sphenopalatine ganglion, and if so, whether by connection with the great superficial or great deep petrosal nerves), it appears that "superior caroticotympanic" is a better descriptive term. In view of the fact that the dissection carried out in this investigation followed this nerve only from the tympanic nerve anteriorly to the carotid artery, this term seems more suitable. The term "inferior caroticotympanic" will be applied to that other filament which was traced from the nerve of Jacobson inferiorly to the carotid artery. The term "common caroticotympanic" will be applied to the short filament where the superior and inferior caroticotympanics left the nerve of Jacobson just prior to dividing. There also existed a short communicating filament, between the superior caroticotympanic and the nerve of Jacobson, which ran superiorly to the point where the latter turned anteriorly to pass the geniculate ganglion.

In addition, two other small filaments were found passing toward the tympanic plexus from the carotid artery between the superior and inferior caroticotympanic nerves, but since they were subsequently found to contain no nerve fibers, further consideration need not be given them.

THE RESULTS OF THE MICROSCOPIC STUDY

In the following presentation the order of description will coincide with that given in the gross anatomy of the parts. In the superior pole of the superior cervical sympathetic ganglion (figure I) there are found three main bundles of fibers; these fibers are of two main types: fine myelinated and fine unmyelinated, and are mingled with each other in no orderly fashion. The bundles are separated by groups of small multipolar ganglion cells. An accurate study of these cells has been made by Dogiel (1896), Ranson (1918) and others, which is somewhat out of the field of discussion in this phase of the problem. Fine fibers can be seen among these ganglion cells (figure II). These fiber bundles merge with one another at the most rostral point of the ganglion and make their way into the internal carotid nerve. In both preparations it can be seen that the myelinated fibers almost entirely enter the branch of the plexus which lies along the inferior surface of the artery (figure III), while only a very few enter the other branches. These fibers have been previously described by Ranson and Billingsley (1918), but their distribution has not been given. That these fibers are postganglionic from the superior cervical ganglion has been proven by Ranson and Billingsley who showed that they are still intact after section of the sympathetic trunk below the superior cervical ganglion and similarly showed that they do not come through rami of communication with the cranial nerves.

At the point of emergence of the great deep petrosal nerve from the carotid plexus (figure IV), it is seen that the abundance of fine myelinated fibers pass on up the artery, while a few seem to pass into the great deep petrosal (this last point is not definite, however). A saall bundle of large and medium-sized myelinated fibers passes from the great deep petrosal into the branch of the carotid plexus which contains the abundance of fine myelinated fibers; this bundle seems to pass toward the cervical sympathetics but is traced with difficulty. Larsell and Fenton (1928) reported the presence of large and medium-sized myelinated fibers which passed from the great deep petrosal and which left the main bundle of the internal carotid plexus and appeared to pass away from the artery, but at this point their material ran out, and the fibers could be traced no farther. The predominating type of fiber in the great deep petrosal, however, is unmyelinated; the fibers of this nerve pass without interruption into the Vidian nerve.

Before tracing the fibers of the great deep petrosal through the Vidian nerve, it would be better to first consider the structure of the great superficial petrosal. In this nerve Larsell and Fenton (1928) found numerous large and smaller myelinated fibers of the sensory type. These findings are corroborated in the present work, and the fibers are seen to continue directly into the Vidian nerve.

In the Vidian nerve the distrituion of the fibers becomes somewhat changed, for at about its mid-point distinct bundles of ganglion cells are found in both the great deep and great superficial petrosal portions. At this point a distinct bundle of unmyelinated fibers can be seen passing from the former into the latter portion and then splitting and running for a short distance in both directions in the great superficial petrosal portion (figure V). From this point rostrally there is an increase in (or at least the presence of) fine myelinated fibers in the great deep petrosal portion. As the Vidian nerve nears the sphenopalatine ganglion, it becomes increasingly difficult to keep the two portions separated by inspection. The Japanese investigators, Kure and Sakurasawa (1929), showed that the unmyelinated fibers in the Vidian nerve completely degenerated after removal of the cervical sympathetic ganglia in the dog, proving experimentally that they come from this region; they made no mention of the myelinated fibers in this nerve.

Concerning the structure of the sphenopalatine ganglia, Larsell and Fenton (1928) showed that it consisted, in the main, of "multipolar cells encircled by fine fibrillary end nets". A like structure has been shown by Carpenter (1912) to exist in this ganglion in the sheep. The fibers which formed these end-nets were traced into the small myelinated fibers (mentioned above) in the great superficial petrosal nerve; these fibers, therefore, are preganglionic. The large myelinated fibers of the great superficial petrosal nerve pass directly through the ganglion into its branches of distribution; they are probably sensory in type. That the facial nerve probably gives sensory fibers through the sphenopalatine ganglion to this region has been shown clinically by Doyle (1923) who demonstrated that sensation of temperature, touch and pain existed in the naso-pharynx of a patient who had previously had operations on the gasserian and petrous ganglia for the relief of trifacial and glossopharyngeal neuralgia. From the deep petrosal nerve the sphenopalatine ganglion receives the unmyelinated and myelinated fibers already mentioned. The distribution of the latter after entering the ganglion has not been determined. Kure' and Sakurasawa (1929) showed that unmyelinated fibers come from the Vidian and also from the maxillary nerve and pass through the ganglion without synapsing; this was proven by the disappearance of the unmyelinated fibers which emerge from the ganglion after severance of the Vidian and maxillary nerves. They also showed that some of the unmyelinated fibers from the great deep petrosal pass into the maxillary nerve, since they degenerated in the maxillary as well as the Vidian nerve after the removal of the cervical sympathetic ganglia in the dog. Small myelinated fibers entered the sphenopalatine ganglion from the maxillary nerve and synapsed within it. Their experimentations further proved that visceral motor fibers pass from the sphenopalatine ganglion to the nasal mucosa and to the lacrimal gland.

In accordance with the gross description the description now turns to the cranial ganglia and their communications. The communicating branch between the superior cervical and vagus contains no nerve fibers, but consists of only fibrous connective tissue. That between the superior cervical ganglion and glossopharyngeus consists of unmyelinated and fine myelinated fibers which originate in the sympathetic ganglion and pass to the petrous ganglion (figure VI). In so doing they pass under the petrous ganglion and terminate in the capsule on the side opposite to the sympathetic trunk. Between the glossopharyngeus and the vagus there exists a very definite bundle of large myelinated fibers. Starting at the side of the ganglion, upon which the just previously described branch from the sympathetic terminates, it passes inferiorly and leaves the ganglion at its inferior pole. It then turns at right angles and breaks up into two bundles: a larger superior and a smaller inferior bundle (figure VII). A small fascicle breaks off from the fibers to the lower bundle near the petrous ganglion; it rejoins the lower bundle near the vagus nerve. The superior bundle turns superiorly on the vagus nerve and runs toward the jugular ganglion; the inferior bundle passes inferiorly toward the nodose ganglion (figure VIII). All the fibers of this branch of communication remain on the side of the vagus near the glossopharyngeus. While these fibers appear to originate in the cells of the petrous ganglion, there is no experimental evidence to prove that such is the case. The other communication between the glossopharyngeus and vagus is found to contain no nerve fibers. It may be of importance to note that in one of the series no communicating fibers can be found between any of these ganglia, showing that there is probably a variation of structure in individual cases.

The vagus nerve consists mainly of myelinated fibers of all sizes, the bulk being large in diameter. The fibers have a tendency to be arranged into fascicles. In one of the series there are found considerable numbers of large unmyelinated fibers just inferior to the jugular ganglion, and numerous fascicles can be seen which collect together in a common trunk within a short distance below the ganglion (figure IX); some of the fibers can be seen winding about the cells of the jugular ganglion. Between the jugular and nodose ganglia the fascicles are distinguished with difficulty; in one of the series fine myelinated fibers can be seen only upon close scrutiny, while in the other large myelinated fibers are easily observed. A few ganglion cells are seen in one of the series at the point where the communicating branch of the glossopharyngeus meets the vagus, but the communicating fibers appear to have no connection with these cells. The fibers again break up into fascicles as the nodose ganglion is reached (figure X), and these fascicles subdivide and wind their way among the ganglion cells (figure XI). In the inferior portion of the ganglion there is a reassembling of large and small myelinated fibers, but most of the large myelinated fibers pass off into the nerves of distribution (figure XI). These observations were also made in the vagus of the dog by Ranson and Chase (1914). They also pointed out that the myelination becomes less marked as the nerve passes inferiorly in its course.

In what appears to be the communication of the accessory at the jugular ganglion there are found to be large and small myelinated and unmyelinated fibers. Ranson and Chase reported having found large medullated with a few small medullated fibers in this root in the dog. In the bulbar root which joins the vagus at the nodose ganglion only large myelinated fibers are found (figure XI); this is in contradiction to the results obtained in the dog by Ranson and Chase who found a predominance of small medullated fibers in the bulbar root. These fibers become part of the common vago-accessory trunk, but there is no common fusion and distribution of the vagus and accessory fibers in the extent of the material which is studied in this work. Ranson and Chase also pointed out that "while the vagus and sympathetic are intimately associated in the neck, it is clear that no considerable part of the non-medullated fibers of the vagus are of sympathetic origin"; it might be remembered that the statement was previously made in this work, that no communicating fibers were found between the superior cervical sympathetic ganglion and the vagus nerve.

In the glossopharyngeal nerve the general structure is very similar to that in the vagus with the exception that small and medium-sized myelinated fibers predominate in the place of the large; a few scattered unmyelinated fibers can be made out upon close scrutiny. There is no obvious suggestion of fasciculation in that portion of the nerve under study. The petrous ganglion, except for its smaller size, presents a picture similar to that of the nodose ganglion.

Before describing the histology of the nerve of Jacobson and the tympanic plexus, it should be stated that no literature on the subject was to be found. While J. Gordon Wilson and others have worked out the intrinsic nerve supply of the tympanic membrane, we have found no reference in the literature pertaining to its extrinsic supply. Perhaps, then, this is a new departure. Only one of the preparations contained the tympanic plexus, and as a result of the confusing anatomical relationships, the difficult osseous dissection, and the delicacy of the nerve filaments, the continuity was broken in three or four places. The fibers have been traced across these gaps as accurately as possible, but it is realized that with their existence the results obtained cannot be given as final. However, as they will aid in subsequent endeavors, it is seen fit to present them.

The nerve of Jacobson leaves the petrous ganglion at its upper pole and passes directly superiorly (figure XII). It consists almost entirely of medium-sized myelinated fibers (and possibly a few unmyelinated fibers). At the point where the filament which runs toward the vagus joins the nerve, there exists a distinct bundle of ganglion cells; these cells extend more along the latter filament than along the main nerve (figure XIII). This latter filament is made up of medium-sized myelinated fibers which are of a somewhat smaller caliber then those in the main nerve. Just as the nerve passes superiorly from this ganglion a small fascicle breaks off rom the main nerve, but travels in the same sheath with it and trails just behind the main nerve bundle (figure XIV). This fascicle, after travelling a short distance in the common sheath, turns to the side and seems to enter the common caroticotympanci nerve. A short distance above this point another fascicle breaks off and seems to join with the filament which joins the superior caroticotympanic nerve. The majority of the fibers continue on into the lesser superficial petrosal nerve. As the latter passes the geniculate ganglion, it receives a fine filament which consists of a few small myelinated fibers, and at the point of union a distinct group of ganglion cells are found in the lesser superficial petrosal nerve (figure XV). The filament of communication sends a very small bundle of fine fibers back past the geniculate ganglion cells and into the greater superficial petrosal nerve (figure XV); it also sends a somewhat larger bundle out into the peripherally directed portion of the facial nerve. The communicating filament between the greater and lesser superficial petrosal nerve contains no nerve fibers. The histology of the lesser superficial petrosal nerve is unchanged from this point on in its course.

From the common caroticotympanic nerve medium-sized myelinated fibers pass into both the superior and inferior caroticotympanic nerve (figures XVI and XVII). The superior nerve receives another bundle from the filament, mentioned above, which joins the nerve of Jacobson. At this point there is found a group of ganglion cells (figure XVI); this last mentioned bundle seems to be directed into the nerve of Jacobson away from the petrous ganglion. The fibers of the superior caroticotympanic are unable to be traced beyond the carotid artery where the nerve ends sharply; no connection with the greater superficial petrosal or the carotid plexus can be demonstrated.

The fibers of the inferior caroticotympanic nerve pass directly inferiorly to the wall of the carotid artery (figure XIV); they follow along its superior edge, and then turn off into the loose tissue below the jugular foramen to be distributed along small blood vessels in this region.

SUMMARY

1. The superior cervical ganglion consists mainly of unmyelinated and very fine myelinated fibers which pass out into the carotid plexus.

2. The preponderance of fine myelinated fibers in the carotid plexus passes on up the artery, while the great deep petrosal is made up, in the main, of unmyelinated fibers.

3. A small bundle of large and medium-sized myelinated fibers is found to pass from the Vidian nerve, into the great deep petrosal, the carotid plexus, and toward the superior cervical ganglion.

4. The great superficial petrosal nerve contains numerous large myelinated fibers and smaller number of small-sized myelinated fibers.

5. The Vidian nerve is found to contain the fibers directly continued from the great superficial and deep petrosal nerve. At the mid-portion of the Vidian nerve a distinct group of ganglion cells is found in both portions, and a bundle of unmyelinated fibers passes from the great deep petrosal portion into the great superficial portion, splits, and runs a short distance in both birections inthe latter. Fine myelinated fibers were found in the great deep petrosal from this point rostrally.

6. In the sphenopalatine ganglion the large myelinated fibers of the great superficial petrosal nerve pass directly

through the ganglion into its branches of distribution. The other fibers in part synapse in the ganglion and in part pass into the maxillary nerve and the nerves of distribution of the ganglion.

7. The communicating branch between the superior cervical and vagus is found to contain no nerve fibers.

8. Between the superior cervical and petrous ganglia the nerve of communication contains unmyelinated and fine myelinated fibers which end in the capsule of the petrous ganglion.

9. The filament between the glossopharyngeus and the vagus passes from the petrous ganglion toward the vagus trunk where it splits, one portion running superiorly toward the jugular ganglion and the other inferiorly into the nodose ganglion.

10. In one of the series no microscopical connections can be found between any of these nerves.

11. The vagus between the jugular and nodose ganglia consists of varying sized myelinated and many large and a few small unmyelinated fibers (the proportion varying markedly in the specimens) arranged into fascicles which collect into a common trunk just above the nodose ganglion. A small bundle of ganglion cells is found between the two main ganglia in one specimen. The fibers break up into fascicles as they enter the nodose ganglion. Below the ganglion the fibers reassemble, but most of the large myelinated fibers pass off into the branches of distribution.

12. The bulbar root consists of large myelinated fibers;

these fibers become part of the common vagus-accessory trunk, but there is no common fusion and distribution of the fibers in the extent studied.

13. In the glossopharyngeal nerve small and medium-sized fibers predominate over the large myelinated fibers. A few scattered unmyelinated fibers are found.

14. The nerve of Jacobson consists almost entirely of medium-sized myelinated fibers which continue on into the lesser superficial petrosal nerve. A small group of ganglion cells is found at the point where the branch which runs toward the vagus leaves the nerve, and another group of cells is found in the lesser superficial petrosal nerve at the point where the communicating branch from the geniculate ganglion meets the nerve.

15. The communicating branch consists fof a few scattered small myelinated fibers some of which pass through the ganglion into the great superficial petrosal nerve. The communicating filament between the great and lesser superficial petrosal nerve is found to contain no nerve fibers.

16. The common caroticotympanic nerve receives medium-sized myelinated fibers from the nerve of Jacobson and sends them into both the superior and inferior caroticotympanic nerves.

17. The superior caroticotympanic receives another similar bundle from the upper filament which joins the nerve of Jacobson. There is found a small group of ganglion cells at the point where it receives this bundle. The superior caroticotympanic fibers can be traced anteriorly to the carotid artery where they sudden-

ly end. No connection with the great superficial petrosal nor the carotid plexus can be found.

18. The fibers of the inferior caroticotympanic nerve pass inferiorly to the carotid artery and then are distributed to small blood vessels in the region below the jugular foramen.

CLINICAL POSSIBILITIES

The explanation of referred pain in affections of the nasopharyngeal region as described by Greenfield Sluder to the ear, mastoid, occiput, back of the neck and shoulder is dependent upon the demonstration of the neuroanatomy of this region.

Larsell and Fenton demonstrated a very probable pathway through the afferent fibers in the greater superficial petrosal to cells in the geniculate ganglion which lay in proximity to cells receiving fibers from the ramus cutaneous facialis going to the mastoid and auricle. This pathway lies in the confines of the distribution of the intermediate nerve and fulfills the postulates of the ganglionic theory of referred pain.

It is still possible, although not demonstrated in this work, that fibers do pass from this region into the glossopharyngeus through the tympanic plexus. From there the distribution of large myelinated fibers to the jugular or IX, X, XI ganglionic mass may account for pain reference into afferent proprioceptive fibers from the trapezius and sternocleidomastoid muscles.

At present ther is no evidence which can lead to the postulation of a fiber tract path through the cervical sympathetics, and still meet the requirements of any theory of referred pain.

If none of these possibilities should prove worthy of consideration, then there can still be postulated a central overflow area in the reticular formation about the solitary tract in which the visceral afferent fibers of the facial end. The vasoconstrictor center could then be involved with resulting vascular spasm and pain in the areas concerned.

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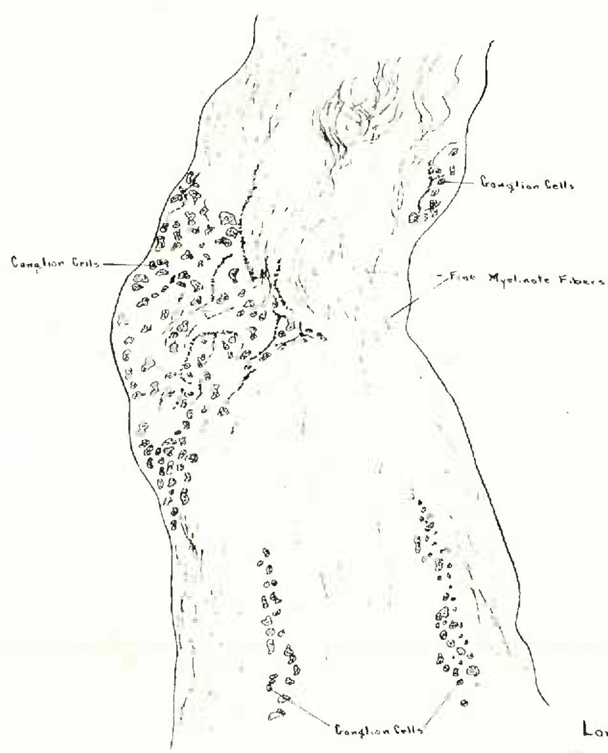
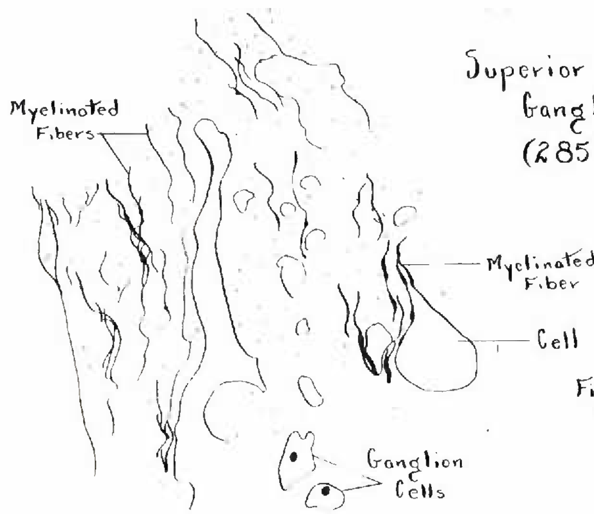


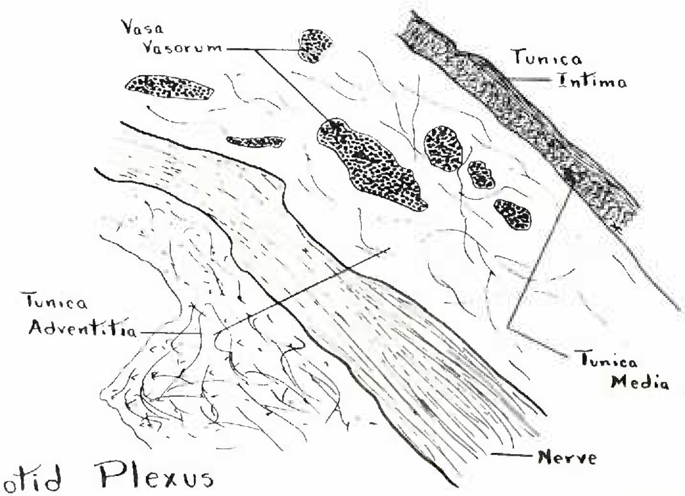
Longitudinal
Section through
the Superior Cervical
Sympathetic Ganglion

Figure 1.



Superior Cervical Ganglion
(285 X)

Figure 2.



Carotid Plexus
(34 X)

Figure 3

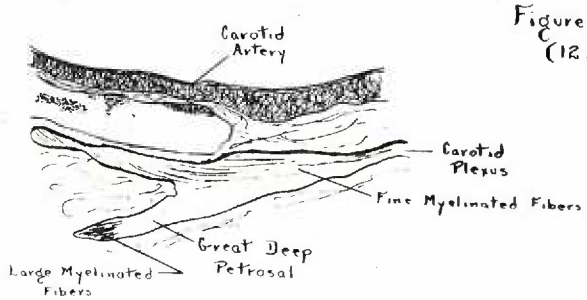
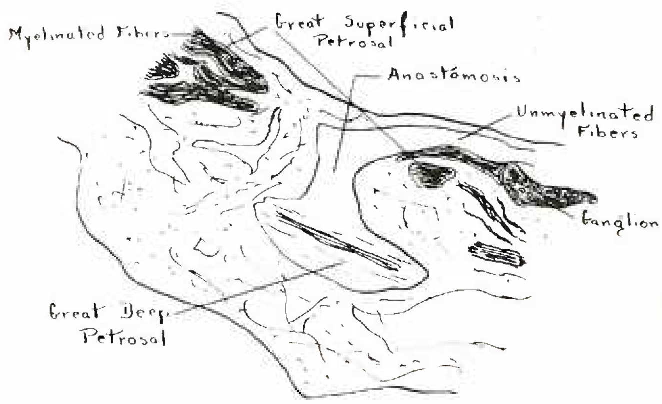
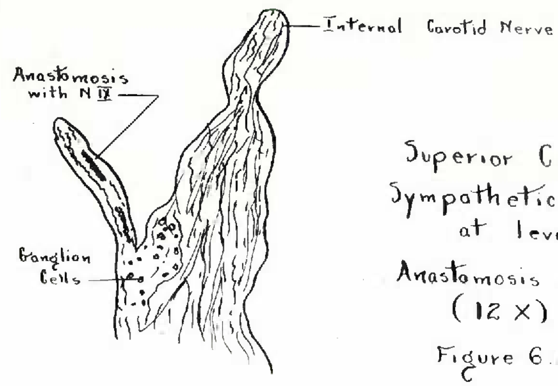


Figure 4.
(12 X)



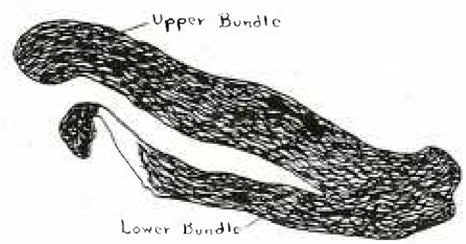
Vidian Nerve
(34 X)

Figure 5



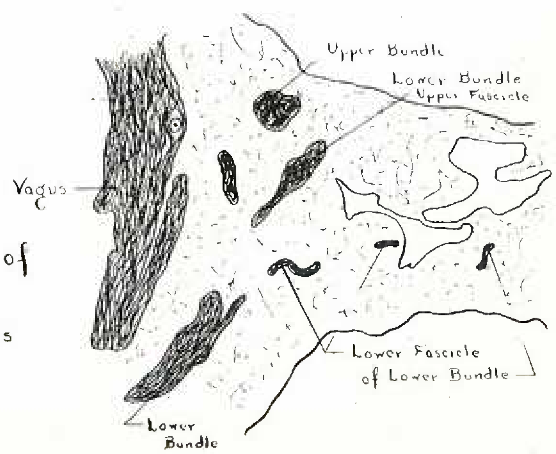
Superior Cervical Sympathetic Ganglion at level of Anastomosis with N IX (12 X)

Figure 6.



Anastomotic Branch between Vagus and Glossopharyngeal (110 X)

Figure 7

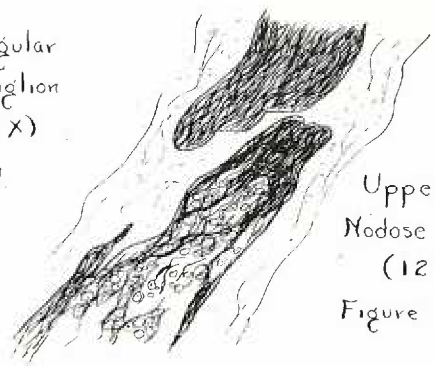


Divisions of IX - X Anastomosis (34 X)

Figure 8.

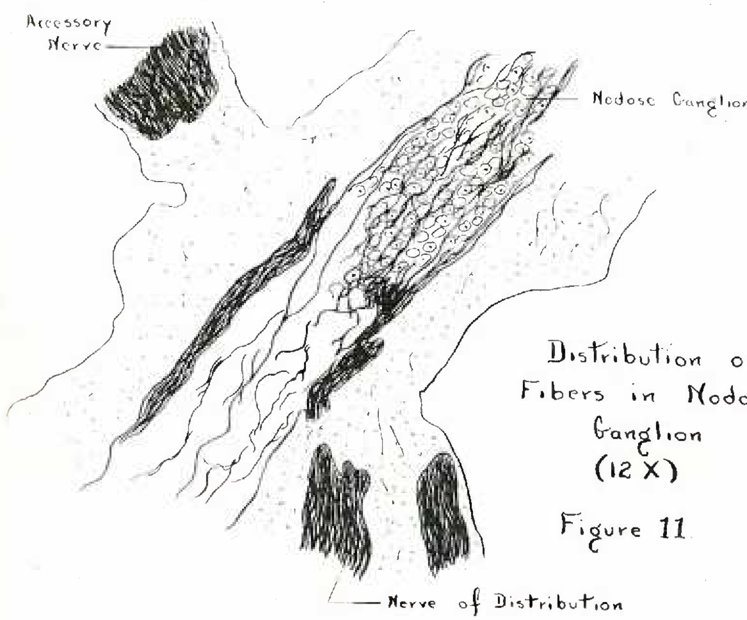
Jugular Ganglion (12 X)

Figure 9.



Upper Pole Nodose Ganglion (12 X)

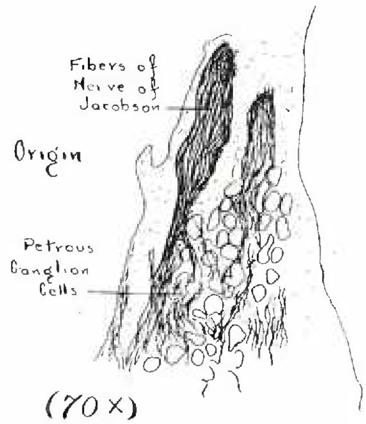
Figure 10.



Distribution of Fibers in Nodose Ganglion (12 X)

Figure 11

Origin



(70X)
Figure 12.

In The
Temporal Bone

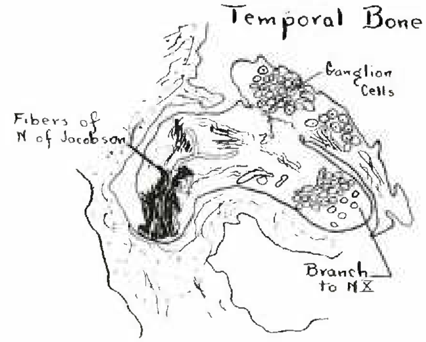
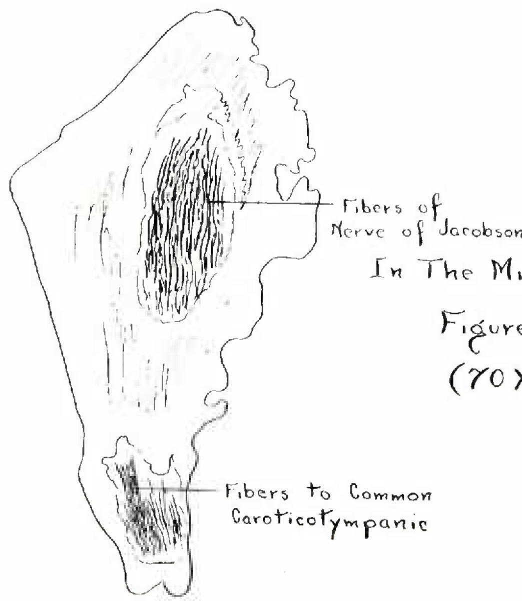


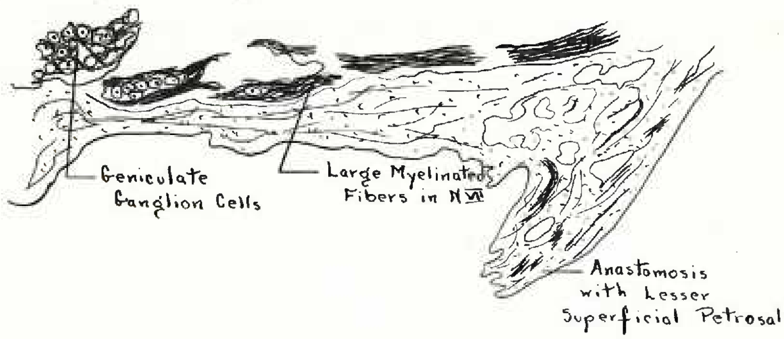
Figure 13.
(70X)



In The Middle Ear

Figure 14.
(70X)

Nerve of
Jacobson



Relation of Lesser
Superficial Petrosal
to Facial Nerve
(46 X)

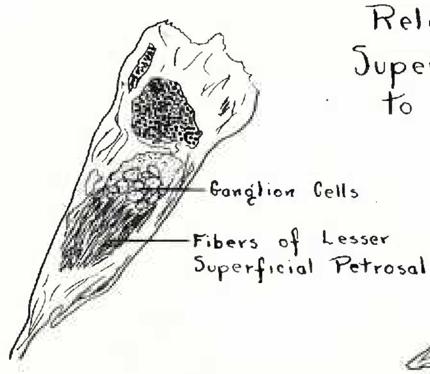


Figure 15.

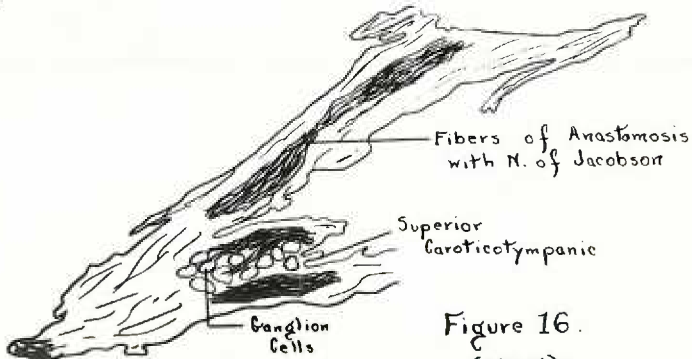
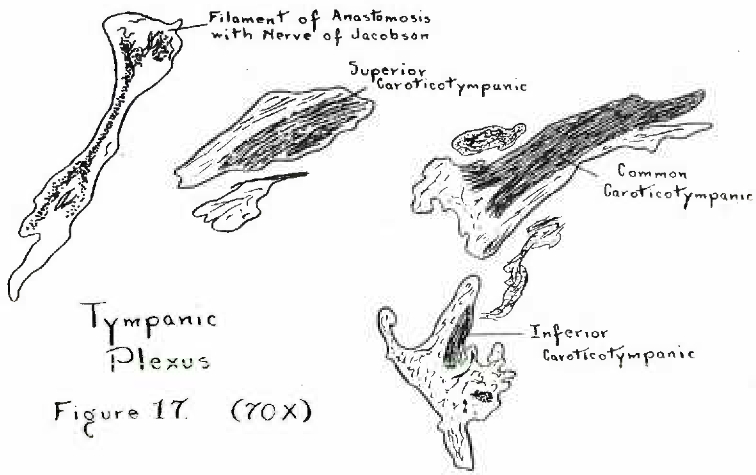


Figure 16.
(70 X)



Tympanic Plexus

Figure 17 (70X)
C

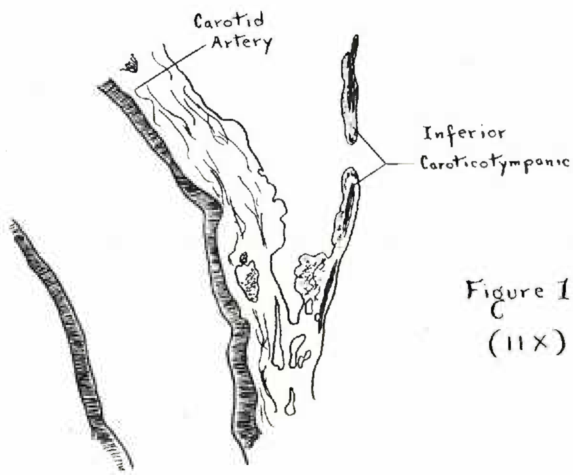
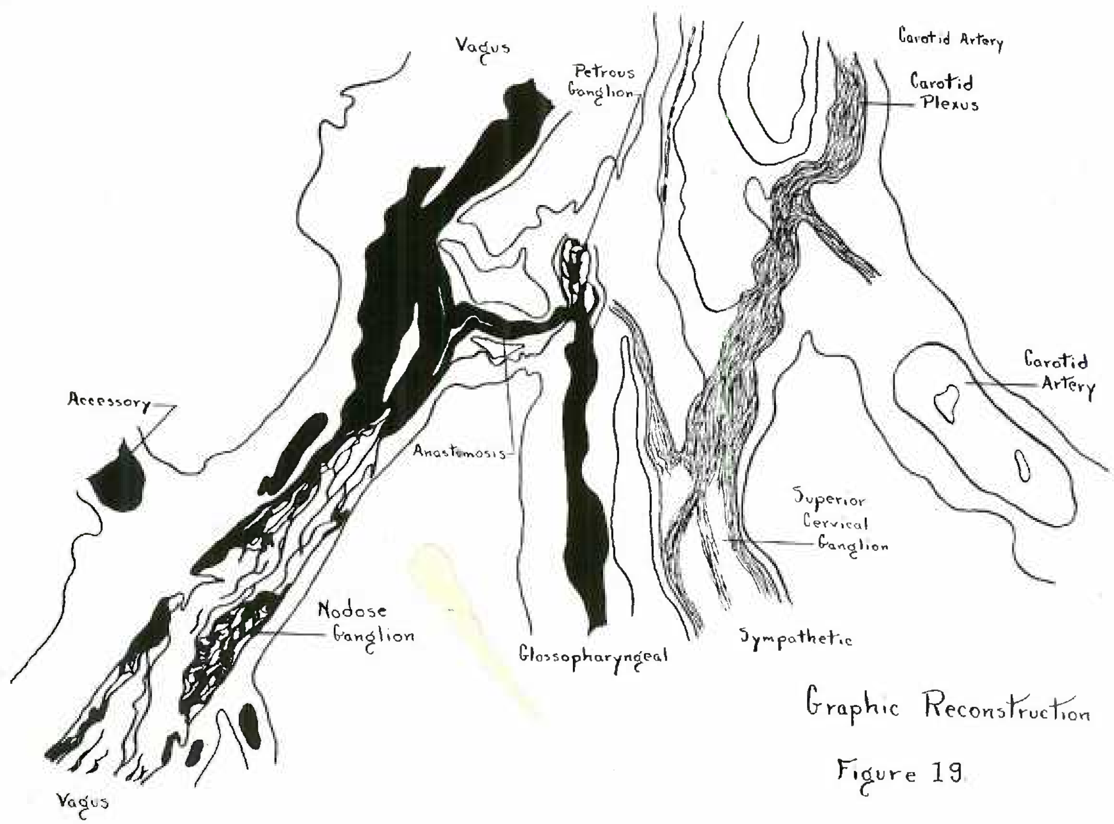
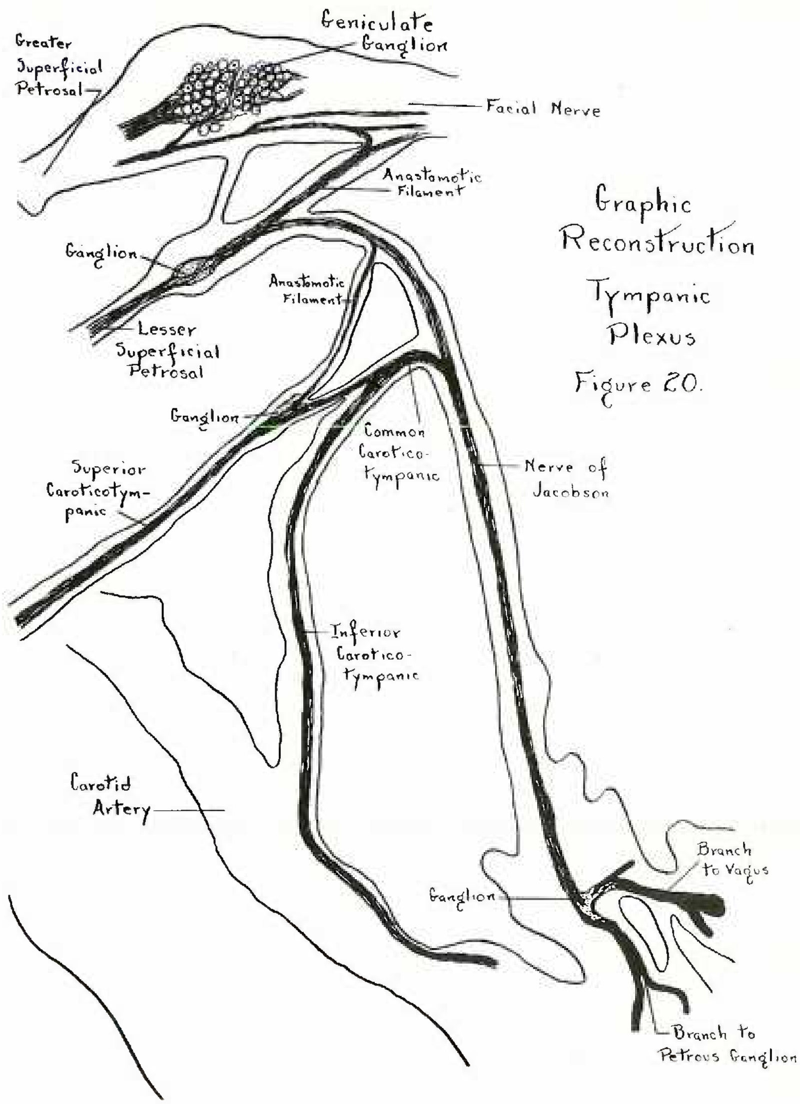


Figure 18
C
(11X)



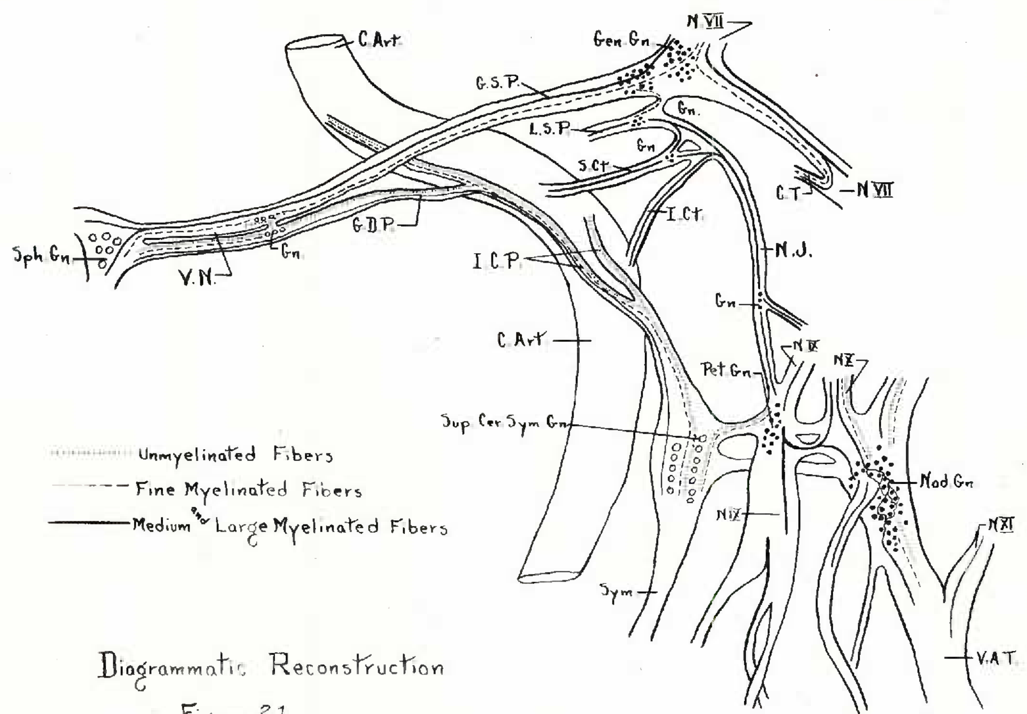
Graphic Reconstruction

Figure 19



Graphic Reconstruction Tympanic Plexus

Figure 20.



Diagrammatic Reconstruction

Figure 21.

Key to Abbreviations in Figure XXI.

C.art.- carotid artery

C.T.- chorda tympani

Gen.Gn.- geniculate ganglion

Gn.- ganglion (groups of cells along the course of nerve)

G.D.P.- great deep petrosal nerve

G.S.P.- great superficial petrosal nerve

I.C.P.- internal carotid plexus

I.Ct.- inferior caroticotympanic nerve

L.S.P.- lesser superficial petrosal nerve

N.J.- nerve of Jacobson

N.VII- facial nerve

N.IX- glossopharyngeal nerve

N.X- vagus nerve

N.XI- accessory nerve

Nod.Gn.- nodose ganglion

Pet.Gn.- petrous ganglion

S.Ct.- superior caroticotympanic nerve

Sph.Gn.- sphenopalatine ganglion

Sup.Cer.Sym.Gn.- superior cervical sympathetic ganglion

Sym.- sympathetic trunk

V.A.T.- vagus-accessory trunk.