to which certain of its filaments are distributed, and its terminal filaments go to the conjunctiva and to the integument of the upper eyelid.

The frontal branch, the largest of the three, divides into the supratrochlear and supraörbital nerves. The supratroachlear passes out of the orbit between the supraörbital foramen and the pulley of the superior oblique muscle. It sends in its course a long, delicate filament to the nasal branch and is finally lost in the integument of the forehead. The supraörbital passes through the supraörbital foramen, sends a few filaments to the upper eyelid, and supplies the forehead, the anterior and the median portions of the scalp, the mucous membrane of the frontal sinus, and the pericranium covering the frontal and parietal bones.

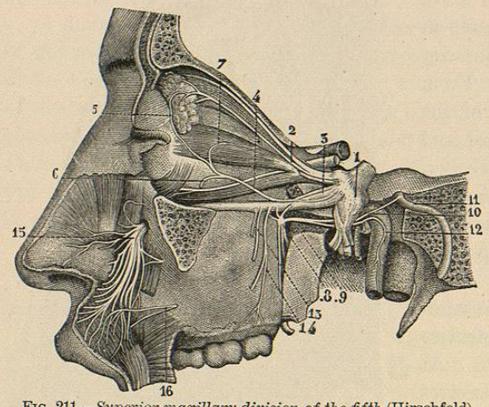

FIG. 211.—*Superior maxillary division of the fifth* (Hirschfeld).
1, ganglion of Gasser; 2, lachrymal branch of the ophthalmic division; 3, *superior maxillary division of the fifth*; 4, *orbital branch*; 5, *lachrymo-palpebral filament*; 6, *malar branch*; 7, *temporal branch*; 8, *spheno-palatine ganglion*; 9, Vidian nerve; 10, great superficial petrosal nerve; 11, facial nerve; 12, branch of the Vidian nerve; 13, *anterior and two posterior dental branches*; 14, *branch to the mucous membrane of the alveolar processes*; 15, *terminal branches of the superior maxillary division*; 16, branch of the facial.

The nasal branch, before it penetrates the orbit, gives off a long, delicate filament to the ophthalmic ganglion. It then gives off the long ciliary nerves, which pass to the ciliary muscle and iris. Its trunk finally divides into the external nasal, or infratrochlearis, and the internal nasal, or ethmoidal. The infratrochlearis is distributed to the integument of the forehead and nose, to the internal surface of the lower eyelid, the lachrymal sac and the caruncula. The internal nasal is distributed to the mucous membrane and also in part to the integument of the nose.

The superior maxillary branch of the fifth passes out of the cranial cavity by the foramen rotundum, traverses the infraörbital canal, and emerges upon the face by the infraörbital foramen. Branches from this nerve are given off in a spheno-maxillary fossa and the infraörbital canal, before it emerges upon the face. In the spheno-maxillary fossa, the first branch is the orbital, which passes into the orbit, giving off one branch, the temporal, which passes through the temporal fossa by a foramen in the malar bone and is distributed to the integument on the temple and the side of the forehead. Another branch, the malar, which likewise emerges by a foramen in the malar bone, is distributed to the integument over this bone. In the spheno-maxillary fossa, are also given off two branches, which pass to the spheno-palatine, or Meckel's ganglion. From this portion of the nerve, branches are given off, the two posterior dental nerves, which are distributed to the

molar and bicuspid teeth, the mucous membrane of the corresponding alveolar processes and to the antrum.

In the infraörbital canal, a large branch, the anterior dental, is given off to the teeth and mucous membrane of the alveolar processes not supplied by the posterior dental branches. This branch anastomoses with the posterior dental.

The terminal branches upon the face are distributed to the lower eyelid (the palpebral branches), to the side of the nose (the nasal branches), anastomosing with the nasal branch of the ophthalmic, and to the integument and the mucous membrane of the upper lip (the labial branches).

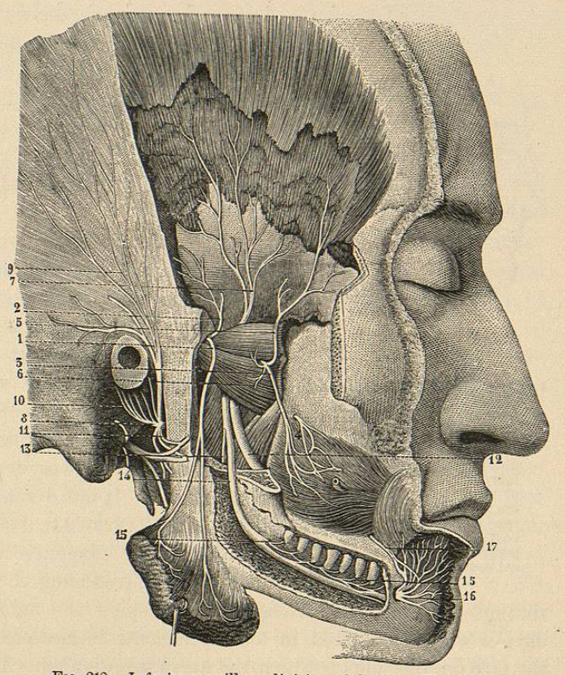

FIG. 212.—*Inferior maxillary division of the fifth* (Hirschfeld).
1, branch from the motor root to the masseter muscle; 2, filaments from this branch to the temporal muscle; 3, buccal branch; 5, 6, 7, branches to the muscles; 8, *auriculo-temporal nerve*; 9, *temporal branches*; 10, *auricular branches*; 11, *anastomosis with the facial nerve*; 12, *lingual branch*; 13, branch of the motor root to the mylo-hyoid muscle; 14, 15, 15, *inferior dental nerve, with its branches*; 16, *mental branch*; 17, *anastomosis of this branch with the facial nerve*.

The inferior maxillary is a mixed nerve, composed of the inferior division of the large root and the entire small root. The distribution of the motor filaments has already been described. This nerve passes out of the cranial cavity by the foramen ovale, and then separates into the anterior division, containing nearly all of the motor filaments, and the posterior division, which is chiefly sensory. The sensory portion breaks up into the following branches:

1. The auriculo-temporal nerve supplies the integument in the temporal region, the auditory meatus, the integument of the ear, the temporo-maxillary articulation and the parotid gland. It also sends branches of communication to the facial.

2. The lingual branch is distributed to the mucous membrane of the tongue as far as the point, the mucous membrane of the mouth, the gums, and to the sublingual gland. This nerve receives a branch from the facial (the chorda tympani) which has already been described. From this nerve,

also, are given off two or three branches which pass to the submaxillary ganglion.

3. The inferior dental nerve, the largest of the three, passes in the substance of the inferior maxillary bone, beneath the teeth, to the mental foramen, where it emerges upon the face. The most important sensory branches are those which supply the pulps of the teeth and the branches upon the face. The nerve, emerging upon the face by the mental foramen, called the mental nerve, supplies the integument of the chin and the lower part of the face and the lower lip. It also sends certain filaments to the mucous membrane of the mouth.

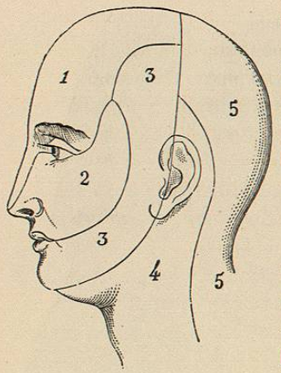

FIG. 213.—*Limits of cutaneous distribution of sensory nerves to the face, head and neck* (Béclard).

1, cutaneous distribution of the ophthalmic division of the fifth; 2, distribution of the superior maxillary division; 3, 3, distribution of the inferior maxillary division; 4, distribution of the anterior branches of the cervical nerves; 5, 5, distribution of the posterior branches of the cervical nerves.

Properties and Uses of the Trifacial.—The trifacial is the great sensory nerve of the face and of the mucous membranes lining the cavities about the head. It is impossible to stimulate this nerve at its origin without seriously involving other parts, but all observations with regard to the properties of the large root go to show that it is an exclusively sensory nerve and that its sensibility is very acute as compared with other nerves. It was divided in the cranial cavity by Mayo (1822–'23), Fodéra (1823) and Magendie (1824). Magendie divided the nerve at its root by introducing a small, cutting stylet through the skull. He succeeded in keeping the animals alive for several days or weeks and noted in his experiments immediate loss of sensibility in the face on the side on which the nerve was divided. The operative procedure employed by Magendie has been followed by other physiologists, particularly Bernard, who made a number of important observations on the immediate and remote effects of section of the nerve. The section is usually made through the ganglion of Gasser. The operation is difficult on account of the danger of wounding large blood-vessels. When this operation is performed without accident, the cornea and the integument and mucous membrane upon that side of the head are instantaneously deprived of sensibility and may be pricked, lacerated or burned, without the slightest evidence of pain on the part of the animal. Almost always the small root of the fifth is divided as well as the large root, and the muscles of mastication are paralyzed upon one side; but with this exception, there is no paralysis of motion, sensation alone being destroyed upon one side.

Immediate Effects of Division of the Trifacial.—This nerve has never been exposed in the cranial cavity in living animals; but its branches upon the face and the lingual branch of the inferior maxillary division have been operated upon and found to be exquisitely sensitive. Physiologists have exposed the roots in animals immediately after death, and have found that

stimulation of the large root carefully insulated produces no muscular contraction. All who have divided this root in living animals must have recognized, not only that it is sensitive, but that its sensibility is far more acute than that of any other nervous trunk in the body.

As far as audition and olfaction are concerned, there are no special effects immediately following section of the trifacial; but there are certain important phenomena observed in connection with the eye and the organs of taste.

At the instant of division of the fifth, the eyeball is protruded and the pupil becomes strongly contracted. This occurs in rabbits, and the contraction of the pupil was observed in the first operations of Magendie. The pupil, however, usually is restored to the normal condition in a few hours. After division of the nerve the lachrymal secretion becomes very much less in quantity; but this is not the cause of the subsequent inflammation, for the eyes are not inflamed, even after extirpation of both lachrymal glands (Magendie). The movements of the eyeball are not affected by division of the fifth.

Another of the immediate effects of complete division of the fifth nerve is loss of general sensibility in the tongue. Most experiments upon the influence of this nerve over the general sensibility and the sense of taste in the tongue have been made by dividing the lingual branch of the inferior maxillary division. When this branch is irritated, there are evidences of intense pain. When it is divided, the general sensibility and the sense of taste are destroyed in the anterior portion of the tongue. It will be remembered, however, that the chorda tympani joins the lingual branch of the fifth as it passes between the pterygoid muscles, and that section of this branch of the facial abolishes the sense of taste in the anterior two-thirds of the tongue. If the gustatory properties of the lingual branch of the fifth be derived from the chorda tympani, lesions of the fifth not involving this nerve would be followed by loss of general sensibility, but the taste would be unaffected. This has been shown to be the fact, by cases of paralysis of general sensibility of the tongue without loss of taste in the human subject, which will be discussed more fully in connection with the physiology of gustation.

Among the immediate effects of section of the fifth, is an interference with the reflex phenomena of deglutition. In a series of observations upon the action of the sensory nerves in deglutition, by Waller and Prevost, it was found that after section of the fifth upon both sides, it was impossible to excite movements of deglutition by stimulating the mucous membrane of the velum palati. After section of the superior laryngeal branches of the pneumogastrics, no movements of deglutition followed stimulation of the mucous membrane of the top of the larynx. In these experiments, when the fifth was divided upon one side, stimulation of the velum upon the corresponding side had no effect, while movements of deglutition were produced by irritating the velum upon the sound side. These experiments show that the fifth nerve is important in the reflex phenomena of deglutition, as a sensory nerve, conveying the impression from the velum palati to the nerve-cen-

tres. This action probably takes place through filaments which pass from the fifth to the mucous membrane, through Meckel's ganglion.

Remote Effects of Division of the Trifacial.—After section of the fifth nerve in the cranial cavity, the immediate loss of sensibility of the integument and mucous membranes of the face and head is usually supplemented by serious disturbances in the nutrition of the eye, the ear and the mucous membranes of the nose and mouth. After a period varying between a few hours and one or two days after the operation, the eye upon the affected side becomes the seat of purulent inflammation, the cornea becomes opaque and ulcerates, the humors are discharged and the organ is destroyed. Congestion of the parts is usually very prominent a few hours after division of the nerve. At the same time there is an increased discharge from the mucous membranes of the nose and mouth upon the affected side, and ulcers appear upon the tongue and lips. It is probable, also, that disorders in the nutrition of the auditory apparatus follow the operation, although these are not so prominent. Animals affected in this way usually die in fifteen to twenty days.

In the early experiments of Magendie, it was noted that "the alterations in nutrition are much less marked" when the division is effected behind the ganglion of Gasser than when it is done in the ordinary way through the ganglion. It is difficult enough to divide the nerve completely, within the cranium, and is almost impossible to make the operation at will through or behind the ganglion; and the phenomena of inflammation are absent only in exceptional and accidental instances. Magendie offered no satisfactory explanation of the differences in the consecutive phenomena coincident with the place of section of the nerve. The facts, however, have been repeatedly verified. In a number of experiments in which the nerve was divided in the cranial cavity (Flint), the consecutive inflammatory effects were almost always observed; but in an experiment made in 1868, the nerve was completely divided on the left side, as was shown by total loss of sensibility of the parts to which it is distributed, and the animal (a rabbit) lived nearly four months. Four days after the operation the loss of sensibility was still complete. There was very little redness of the conjunctiva of the left eye, and a very slight streak of opacity, so slight that it was distinguished with difficulty. Twelve days after the operation the sensibility of the left eye was distinct but slight. There was no redness of the conjunctiva, and the opacity of the cornea had disappeared. The animal was in good condition, and the line of contact of the upper with the lower incisors, when the jaws were closed, was very oblique. The animal was kept alive by careful feeding with bread and milk for one hundred and seven days after the operation, and there was no inflammation of the organs of special sense. It died at that time of inanition, having become extremely emaciated. The animal never recovered power over the muscles of the left side, and the incisors grew to a great length, interfering very much with mastication.

Longet, in 1842, gave an explanation of the absence of inflammation in certain cases of division of the fifth. He attributed the consecutive inflammation in most experiments to lesion of the ganglion of Gasser and of the sympathetic connections, which are very abundant at this point. These sympathetic filaments are avoided when the section is made behind the ganglion.

The explanation of the phenomena of disordered nutrition in the organs of special sense, particularly the eye, following division of the fifth, is not afforded by the section of this nerve alone; for when the loss of sensibility is complete after division of the nerve behind the Gasserian ganglion, these results may not follow. They are not explained by deficiency in the lachrymal secretion, for they are not observed when both lachrymal glands have been extirpated. They are not due to exposure of the eyeball, for they do not follow section of the facial. They are not due simply to an enfeebled general condition, for in the experiment just detailed, the animal died of inanition after section of the nerve, without any evidences of inflammation. In view of the fact that section of the sympathetic filaments is well known to modify nutrition of parts to which they are distributed, producing congestion, increase in temperature and other phenomena, it is rational to infer that the modifications in nutrition which follow section of the fifth after it receives filaments from the sympathetic system, not occurring when these sympathetic filaments escape division, are to be attributed to lesion of the sympathetic and not to the division of the sensory nerve itself.

A farther explanation is demanded for the inflammatory results which follow division of the sympathetic filaments joining the fifth, inasmuch as division of the sympathetic alone in the neck simply produces exaggeration of the nutritive processes, as evidenced chiefly by local increase in the animal temperature, and not the well-known phenomena of inflammation.

It was remarked by Bernard that the "alterations in nutrition appear more promptly in animals that are enfeebled." Section of the small root of the fifth, which is unavoidable when the nerve is divided within the cranial cavity, generally interferes so much with mastication as to influence seriously the general nutrition; and this might modify the nutritive processes in delicate organs, like the eye, so as to induce those changes which are called inflammatory. The following observation (W. H. Mason) has an important bearing on this question:

The fifth pair of nerves was divided in a cat in the ordinary way. By feeding the animal carefully with milk and finely chopped meat, the nutrition was maintained at a high standard, and no inflammation of the eye occurred for about four weeks. The supply of food was then diminished to about the quantity it would be able to take without any special care, when the eye became inflamed, and perforation of the cornea and destruction of the organ followed. The animal was kept for about five months; at the end of which time, sensation upon the affected side, which had been gradually improving, was completely restored.

The following explains, in a measure at least, the consecutive inflammatory effects of section of the fifth with its communicating sympathetic filaments: By dividing the sympathetic, the eye and the mucous membranes of

the nose, mouth and ear are rendered hyperæmic, the temperature probably is raised, and the processes of nutrition are exaggerated. This condition of the parts would seem to require a full supply of nutritive material from the blood, in order to maintain the condition of exaggerated nutrition; but when the blood is impoverished—probably as the result of deficiency in the introduction of nutritive matter, from paralysis of the muscles of mastication upon one side—the nutritive processes in these delicate parts are seriously modified, so as to constitute inflammation. The observation just detailed is an argument in favor of this view; for here the inflammation was arrested when the action of the paralyzed muscles was supplied by careful feeding. With this view, the disorders of nutrition observed after division of the fifth may properly be referred to the sympathetic system.

Pathological facts in confirmation of experiments upon the fifth pair in the lower animals are not wanting; but it must be remembered that in cases of paralysis of the nerve in the human subject, it is not always possible to locate exactly the seat of the lesion and to appreciate fully its extent, as can be done when the nerve is divided by an operation. In studying these cases, it sometimes occurs that the phenomena, particularly those of modified nutrition, are more or less contradictory.

In nearly all works upon physiology, are references to cases of paralysis of the fifth in the human subject. Two cases have been reported by Noyes, in both of which there was inflammation of the eye. In one case the tongue was entirely insensible upon one side, but there was no impairment of the sense of taste. A notable feature in one of the cases was the fact that an operation upon the eyelid of the affected side was performed without the slightest evidence of pain on the part of the patient.

Cases of paralysis of the fifth in the human subject in the main confirm the results of experiments upon the inferior animals. In cases in which the fifth nerve alone is involved in the disease, without the facial, there is simply loss of sensibility upon one side, the movements of the superficial muscles of the face being unaffected. When the small root is involved, the muscles of mastication upon one side are paralyzed; but in certain reported cases in which this root escaped, there was no muscular paralysis. The senses of sight, hearing and smell, except as they were affected by consecutive inflammation, are little if at all disturbed in uncomplicated cases. The sense of taste in the anterior portion of the tongue is perfect, except in those cases in which the facial, the chorda tympani or the lingual branch of the fifth after it had been joined by the chorda tympani is involved in the disease. In some cases there is no alteration in the nutrition of the organs of special sense; but in this respect the facts with regard to the seat of the lesion are not so satisfactory as in experiments upon the lower animals, it being difficult, in most of them, to exactly limit the boundaries of the lesion.

Pneumogastric (Tenth Nerve).

Of all the nerves emerging from the cranial cavity, the pneumogastric presents the greatest number of anastomoses, the most remarkable course and

the most varied uses. Arising from the medulla oblongata by a purely sensory root, it communicates with at least five motor nerves, and it is distributed largely to muscular tissue, both of the voluntary and the involuntary variety.

Physiological Anatomy.—The apparent origin of the pneumogastric is from the lateral portion of the medulla oblongata, just behind the olivary body, between the roots of the glosso-pharyngeal and the spinal accessory. The deep origin is mainly from what is called the nucleus of the pneumogastric, in the inferior portion of the gray substance in the floor of the fourth ventricle. The course of the fibres, traced from without inward, is somewhat intricate.

The deep origins of the pneumogastric and glosso-pharyngeal nerves appear to be in the main identical. Tracing the filaments from without inward, they may be followed in four directions: (1) The anterior filaments pass from without inward, first very superficially, in the direction of the olivary body; but they then turn and pass deeply into the substance of the restiform body, in which they are lost. (2) The posterior filaments are superficial, and they pass, with the fibres of the restiform body, toward the cerebellum. (3) Of the intermediate filaments, the anterior pass through the restiform body, the greatest number extending to the median line, in the floor of the fourth ventricle. A few fibres are lost in the middle fasciculi of the medulla and a few pass toward the brain. (4) The posterior intermediate filaments traverse the restiform body, to the floor of the fourth ventricle, when some pass to the median line, and others descend in the substance of the medulla. It is difficult to follow the fibres of origin of the pneumogastrics beyond the median line; but recent observations leave no doubt of the fact that many of these fibres decussate in the floor of the fourth ventricle.

There are two ganglionic enlargements belonging to the pneumogastric. In the jugular foramen, is a well marked, grayish, ovoid enlargement, one-sixth to one-fourth of an inch (4·2 to 6·4 mm.) in length, called the jugular ganglion, or the ganglion of the root. This is united by two or three filaments with the ganglion of the glosso-pharyngeal. It is a true ganglion, containing nerve-cells. After the nerve has emerged from the cranial cavity, it presents on its trunk another grayish enlargement, half an inch to an inch (12 to 25 mm.) in length, called the ganglion of the trunk. This has a plexiform structure, the white fibres being mixed with grayish fibres and nerve-cells. The exit of the nerve from the cranial cavity is by the jugular foramen, or posterior foramen lacerum, in company with the spinal accessory, the glosso-pharyngeal nerve and the internal jugular vein.

Anastomoses.—There are occasional filaments of communication which pass from the spinal accessory to the ganglion of the root of the pneumogastric, but these are not constant. After both nerves have emerged from the cranial cavity, an important branch of considerable size passes from the spinal accessory to the pneumogastric, with which it becomes closely united. Experiments have shown that these filaments from the spinal accessory pass in great part to the larynx, by the inferior laryngeal nerves.

In the aquæductus Fallopii, the facial nerve gives off a filament of communication to the pneumogastric, at the ganglion of the root. This filament, joined at the ganglion by sensory filaments from the pneumogastric and some filaments from the glosso-pharyngeal, is called the auricular branch of Arnold. By some anatomists it is regarded as a branch from the facial, and by others it is described with the pneumogastric.

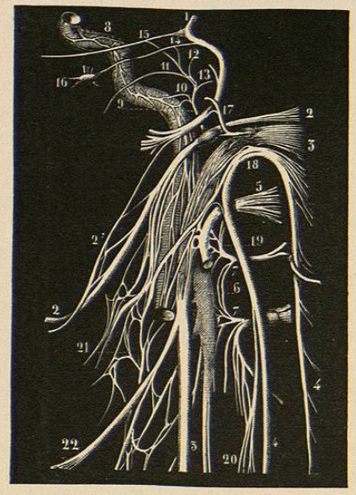

FIG. 214.—*Anastomoses of the pneumogastric* (Hirschfeld).

1, facial nerve; 2, glosso-pharyngeal nerve; 2′, anastomoses of the glosso-pharyngeal with the facial; 3, 3, *pneumogastric, with its two ganglia;* 4, 4, *spinal accessory;* 5, sublingual nerve; 6, superior cervical ganglion of the sympathetic; 7, *anastomotic arcade of the first two cervical nerves;* 8, carotid branch of the superior cervical ganglion of the sympathetic; 9, nerve of Jacobson; 10, branches of this nerve to the sympathetic; 11, branch to the Eustachian tube; 12, branch to the fenestra ovalis; 13, branch to the fenestra rotunda; 14, external deep petrous nerve; 15, internal deep petrous nerve; 16, otic ganglion; 17, *auricular branch of the pneumogastric;* 18, *anastomosis of the pneumogastric with the spinal accessory;* 19, *anastomosis of the pneumogastric with the sublingual;* 20, anastomosis of the spinal accessory with the second pair of cervical nerves; 21, pharyngeal plexus; 22, superior laryngeal nerve.

Two or three small filaments of communication pass from the sublingual to the ganglion of the trunk of the pneumogastric.

At the ganglion of the trunk, the pneumogastric generally receives filaments of communication from the arcade formed by the anterior branches of the first two cervical nerves. These, however, are not constant.

The pneumogastric is connected with the sympathetic system by a number of filaments of communication from the superior cervical ganglion, passing in part upward toward the ganglion of the root of the pneumogastric, and in part transversely and downward. These filaments frequently are short, and they bind the sympathetic ganglion to the trunk of the nerve. The main trunk of the pneumogastric and its branches receive a few filaments of communication from the middle and inferior cervical and the upper dorsal ganglia of the sympathetic.

The pneumogastric frequently sends a slender filament to the glosso-pharyngeal nerve, at or near the ganglion of Andersch. Branches from the pneumogastric join branches from the glosso-pharyngeal, the spinal accessory and the sympathetic, to form the pharyngeal plexus.

Distribution.—Although the pneumogastric nerves upon the two sides do not present any important differences in the destination of their filaments, as far down as the diaphragm, the distribution of the abdominal branches is not the same. The most important branches are the following:

1. Auricular.
2. Pharyngeal.
3. Superior laryngeal.
4. Inferior, or recurrent laryngeal.
5. Cardiac, cervical and thoracic.
6. Pulmonary, anterior and posterior.
7. Œsophageal.
8. Abdominal.

The auricular nerves are sometimes described in connection with the facial. They are given off from the ganglion of the trunk of the pneumogastric and are composed of filaments of communication from the facial and from the glosso-pharyngeal, as well as of filaments from the pneumogastric itself. The nerves thus constituted are distributed to the integument of the upper portion of the external auditory meatus, and a small filament is sent to the membrana tympani.

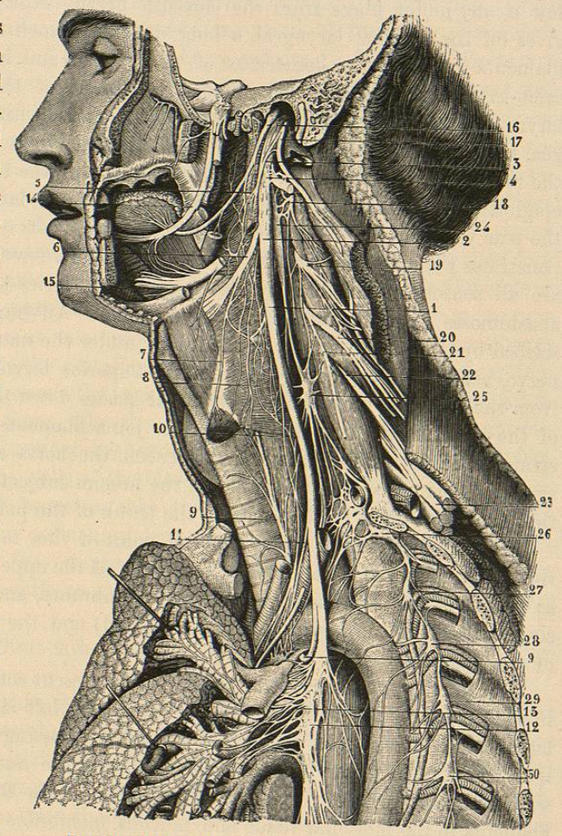

FIG. 215.—*Distribution of the pneumogastric* (Hirschfeld).

1, *trunk of the left pneumogastric;* 2, *ganglion of the trunk;* 3, *anastomosis with the spinal accessory;* 4, *anastomosis with the sublingual;* 5, *pharyngeal branch (the auricular branch is not shown in the figure);* 6, *superior laryngeal branch;* 7, *external laryngeal nerve;* 8, *laryngeal plexus;* 9, 9, *inferior laryngeal branch;* 10, *cervical cardiac branch;* 11, *thoracic cardiac branch;* 12, 13, *pulmonary branches;* 14, lingual branch of the fifth; 15, lower portion of the sublingual; 16, glosso-pharyngeal; 17, spinal accessory; 18, 19, 20, spinal nerves; 21, phrenic nerve; 22, 23, spinal nerves; 24, 25, 26, 27, 28, 29, 30, sympathetic ganglia.

The pharyngeal nerves are given off from the superior portion of the ganglion of the trunk, and they contain a large number of the filaments of communication which the pneumogastric receives from the spinal accessory. In their course by the sides of the superior constrictor muscles of the pharynx, these nerves anastomose with filaments from the glosso-pharyngeal and the superior cervical ganglion of the sympathetic, to form what is known as the pharyngeal plexus. The ultimate filaments of distribution pass to the muscles and the mucous membrane of the pharynx. Physiological experiments have shown that the motor influence transmitted to the pharyngeal muscles through the pharyngeal branches of the pneumogastric is derived from the spinal accessory.

The superior laryngeal nerves are given off from the lower part of the ganglion of the trunk. Their filaments come from the side opposite to the