CHAPTER XVII.

SPINAL AND CRANIAL NERVES.

Spinal nerves—Cranial nerves—Anatomical classification—Physiological classification—Motor oculi communis (third nerve)—Physiological anatomy—Properties and uses—Influence upon the movements of the iris—Patheticus, or trochlearis (fourth nerve)—Physiological anatomy—Properties and uses—Motor oculi externus, or abducens (sixth nerve)—Physiological anatomy—Properties and uses—Nerve of mastication (the small, or motor root of the fifth)—Physiological anatomy—Properties and uses—Facial, or nerve of expression (seventh nerve)—Physiological Anatomy—Intermediary nerve of Wrisberg—Alternate paralysis—General properties—Uses of the chorda tympani—Influence of various branches of the facial upon the movements of the palate and uvula—Spinal accessory (eleventh nerve)—Physiological anatomy—Uses of the internal branch from the spinal accessory to the pneumogastric—Influence of the spinal accessory upon the heart—Uses of the external, or muscular branch of the spinal accessory—Sublingual, or hypoglossal (twelfth nerve)—Physiological anatomy—Properties and uses—Trifacial, or trigeminal (fifth nerve)—Physiological anatomy—Properties and uses—Pneumogastric (tenth nerve)—Physiological anatomy—Properties and uses—General properties of the roots—Properties and uses of the auricular nerves—Properties and uses of the pharyngeal nerves—Properties and uses of the superior laryngeal nerves—Properties and uses of the inferior, or recurrent laryngeal nerves—Properties and uses of the cardiac nerves—Depressor nerve of the circulation—Properties and uses of the pulmonary nerves—Properties and uses of the œsophageal nerves—Properties and uses of the abdominal nerves.

WITH a knowledge of the general properties of the nerves belonging to the cerebro-spinal system, it is easy to understand the uses of most of the special nerves, simply from their anatomical relations. This is especially true of the spinal nerves. These, in general terms, are distributed to the muscles of the trunk and extremities, to the sphincters and the integument covering these parts, the posterior segment of the head, and to certain mucous membranes. It is evident, therefore, that an account of the exact office of each nervous branch would necessitate a full description, not only of the nerves, but of the muscles of the body, which is manifestly within the scope only of treatises on descriptive anatomy.

SPINAL NERVES.

There are thirty-one pairs of spinal nerves; eight cervical, twelve dorsal, five lumbar, five sacral and one coccygeal. Each nerve arises from the spinal cord by an anterior (motor) and a posterior (sensory) root, the posterior roots being the larger and each having a ganglion. Immediately beyond the ganglion, the two roots unite into a single mixed nerve, which passes out of the spinal canal by the intervertebral foramen. The nerve thus constituted is possessed of motor and sensory properties. It divides outside of the spinal canal into two branches, anterior and posterior, both containing motor and sensory filaments, which are distributed respectively to the anterior and the posterior parts of the body. The anterior branches are the larger, and they supply the limbs and all parts in front of the spinal column.

The anterior branches of the upper four cervical nerves form the cervical plexus, and the four inferior cervical nerves, with the first dorsal, form the brachial plexus. The anterior branches of the dorsal nerves, with the exception of the first, supply the walls of the chest and abdomen. These nerves go directly to their distribution and do not first form a plexus. The anterior branches of the upper four lumbar nerves form the lumbar plexus. The anterior branch of the fifth lumbar nerve and a branch from the fourth unite with the anterior branch of the first sacral, forming the lumbo-sacral nerve, and enter into the sacral plexus. The upper three anterior sacral nerves, with a branch from the fourth, form the sacral plexus. The greatest portion of the fourth anterior sacral is distributed to the pelvic viscera and the muscles of the anus. The fifth anterior sacral and the coccygeal are distributed to parts about the coccyx.

The posterior branches of the spinal nerves are very simple in their distribution. With one or two exceptions, which have no great physiological importance, these nerves pass backward from the main trunk, divide into two branches, external and internal, and their filaments of distribution go to the muscles and to integument behind the spinal column.

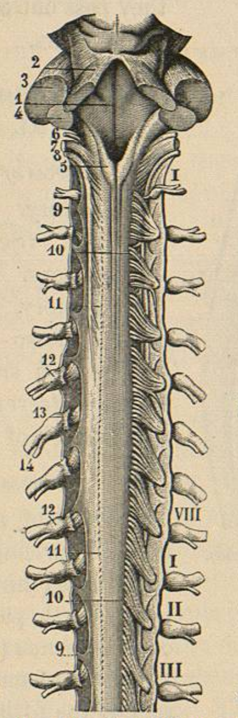

FIG. 190.—*Cervical portion of the spinal cord* (Hirschfeld).

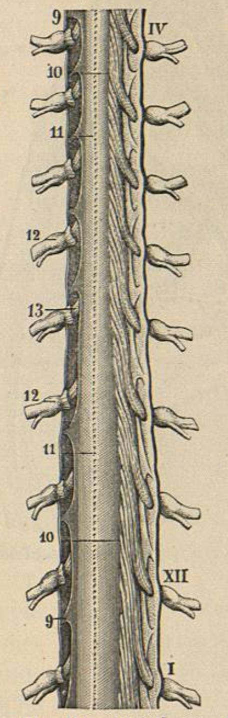

FIG. 191.—*Dorsal portion of the spinal cord* (Hirschfeld).

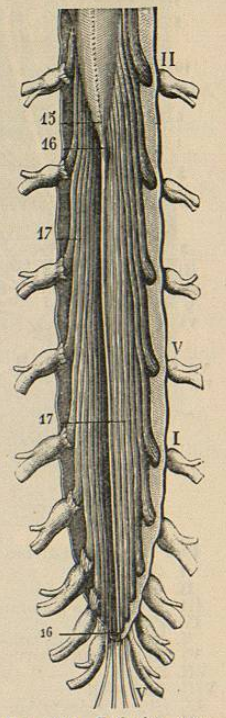

FIG. 192.—*Inferior portion of the spinal cord, and cauda equina* (Hirschfeld).

1, antero-inferior wall of the fourth ventricle; 2, superior peduncle of the cerebellum; 3, middle peduncle of the cerebellum; 4, inferior peduncle of the cerebellum; 5, inferior portion of the posterior median columns of the cord; 6, glosso-pharyngeal nerve; 7, pneumogastric; 8, spinal accessory nerve; 9, 9, 9, 9, dentated ligament; 10, 10, 10, 10, *posterior roots of the spinal nerves*; 11, 11, 11, 11, *posterior lateral groove*; 12, 12, 12, 12, *ganglia of the posterior roots of the nerves*; 13, 13, *anterior roots of the nerves*; 14, *division of the nerves into two branches*; 15, lower extremity of the cord: 16, 16, coccygeal ligament; 17, 17, cauda equina; I-VIII, *cervical nerves*; I, II, III, IV-XII, *dorsal nerves*; I, II-V, *lumbar nerves*; I-V, *sacral nerves*.

It is farther important to note, that all of the cerebro-spinal nerves anastomose with the sympathetic.

CRANIAL NERVES.

Many of the cranial nerves are peculiar, either as regards their general properties or in their distribution to parts concerned in special functions. In some of these nerves, the most important facts concerning their distribution have been ascertained only by physiological experimentation, and their anatomy is inseparably connected with their physiology. It would be desirable, if it were possible, to classify these nerves with reference strictly to their properties and uses; but this can be done only to a certain extent. The classification of the cranial nerves adopted by most anatomists is the arrange-

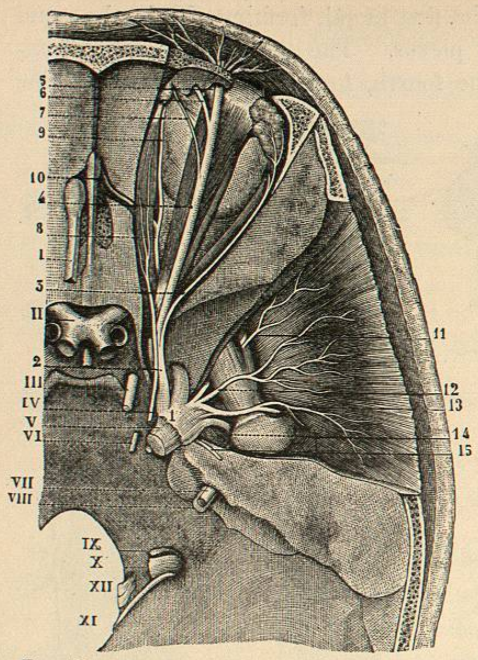

FIG. 193.—*Roots of the cranial nerves* (Hirschfeld).
I. Olfactory.
II. Optic.
III. Motor oculi communis.
IV. Patheticus.
V. Nerve of mastication and trifacial.
VI. Motor oculi externus.
VII. Facial.
VIII. Auditory.
IX. Glosso-pharyngeal.
X. Pneumogastric.
XI. Spinal accessory.
XII. Sublingual.
The numbers 1 to 15 refer to branches which will be described hereafter.

ment of Sömmerring, in which the nerves are numbered from before backward, in the order in which they pass out of the skull, making twelve pairs.

Classification of the Cranial Nerves.

Nerves of Special Sense.

Olfactory. (First pair.)
Optic. (Second pair.)
Auditory. (Eighth pair.)
Gustatory, comprising a part of the glosso-pharyngeal (ninth pair) and a small filament from the facial (seventh pair) to the lingual branch of the fifth pair.

Nerves of Motion.

Nerves of motion of the eyeball, comprising the motor oculi communis (third pair), the patheticus (fourth pair), and the motor oculi externus (sixth pair).
Nerve of mastication, or motor root of the fifth pair.
Facial, sometimes called the nerve of expression. (Seventh pair.)
Spinal accessory. (Eleventh pair.)
Sublingual. (Twelfth pair).

Nerves of General Sensibility.

Trifacial, or large root of the fifth pair.
A portion of the glosso-pharyngeal. (Ninth pair.)
Pneumogastric. (Tenth pair.)

In the above arrangement, the nerves are classified according to their properties at their roots. In their course, some of these nerves become mixed and their branches are both motor and sensory, such as the pneumogastric and the inferior maxillary branch of the trifacial.

The nerves of special sense have little or no general sensibility; and with the exception of the gustatory nerves, they do not present a ganglion on their roots, in this, also, differing from the ordinary sensory nerves. They are capable of conveying to the nerve-centres only certain peculiar impressions, such as odors, for the olfactory nerves, light, for the optic nerves, and

sound, for the auditory nerves. The proper transmission of these impressions, however, involves the action of accessory parts, more or less complex; and the properties of these nerves will be fully considered in connection with the physiology of the special senses.

Motor Oculi Communis (Third Nerve).

The third cranial nerve is the most important of the motor nerves distributed to the muscles of the eyeball. Its physiology is readily understood in connection with its distribution, the only point at all obscure being its relations to the movements of the iris, upon which the results of experiments are somewhat contradictory.

Physiological Anatomy.—The apparent origin of the third nerve is from the inner edge of the crus cerebri, directly in front of the pons Varolii, midway between the pons and the corpora albicantia. It presents here eight or ten filaments, of nearly equal size, which soon unite into a single, rounded trunk.

The deep origin of the nerve has been studied by dissections of the encephalon fresh and hardened by different liquids. From the groove by which they emerge from the encephalon, the fibres spread out in a fan-shape, the middle filaments passing inward, the anterior, inward and forward, and the posterior, inward and backward. It is probable that the middle filaments pass to the median line and decussate with corresponding fibres from the opposite side. The anterior filaments pass forward and are lost in the optic thalamus. The posterior filaments on either side pass backward to a gray nucleus beneath the aqueduct of Sylvius and here decussate with fibres from the opposite side. This decussation of the fibres of origin of the third nerves is important in connection with the harmony of action of the iris and the muscles of the eyes upon the two sides.

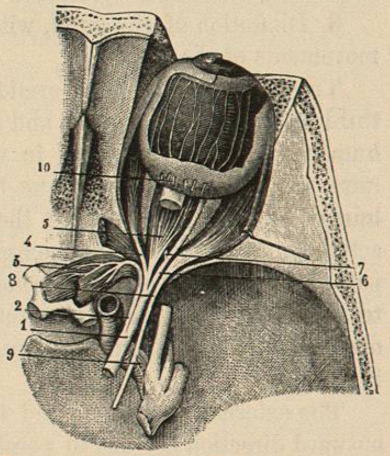

FIG. 194.—*Distribution of the motor oculi communis* (Hirschfeld).
1, *trunk of the motor oculi communis*; 2, *superior branch*; 3, *filaments which this branch sends to the superior rectus and the levator palpebri superioris*; 4, *branch to the internal rectus*; 5, *branch to the inferior rectus*; 6, *branch to the inferior oblique muscle*; 7, *branch to the lenticular ganglion*; 8, motor oculi externus; 9, filaments of the motor oculi externus anastomosing with the sympathetic; 10, *ciliary nerves.*

The distribution of the third nerve is very simple. As it passes into the orbit, by the sphenoidal fissure, it divides into two branches. The superior, which is the smaller, passes to the superior rectus muscle of the eye, and certain of its filaments are continued to the levator palpebræ superioris. The inferior division breaks up into three branches. The internal branch passes to the internal rectus muscle; the inferior branch, to the inferior rectus; the external branch, the largest of the three, is distributed to the inferior oblique muscle, and in its course, it sends a short and thick filament to the lenticular, or ophthalmic ganglion of the sympathetic. It is this branch which is supposed, through the short ciliary nerves passing from the lenticular ganglion, to furnish the motor influence to the iris. In its course this nerve receives a few very delicate filaments from the cavernous plexus of the sympathetic and a branch from the ophthalmic division of the trifacial.

Properties and Uses of the Motor Oculi Communis.—Stimulation of the root of the third nerve in a living animal produces contraction of the muscles to which it is distributed, but no pain. If the stimulus, however, be applied a little farther on in the course of the nerve, there are evidences of sensibility; and this is readily explained by its communications with the ophthalmic branch of the trifacial. At its root, therefore, this nerve is exclusively motor, and its office is connected entirely with the action of muscles.

The phenomena which are observed after section of the motor oculi communis in living animals are the following:

1. Falling of the upper eyelid, or blepharoptosis.
2. External strabismus, immobility of the eye except in an outward direction, inability to rotate the eye on its antero-posterior axis in certain directions, with slight protrusion of the eyeball.
3. Dilatation of the pupil, with a certain degree of interference with the movements of the iris.

The falling of the upper eyelid is constantly observed after division of the third nerve in living animals and always follows its complete paralysis in the human subject. An animal in which the nerve has been divided can not raise the lid, but can press the lids together by a voluntary effort. In the human subject the falling of the lid gives to the face a peculiar and characteristic expression. The complete loss of power shows that the levator palpebræ superioris muscle depends upon the third nerve entirely for its motor filaments. In pathology, external strabismus is frequently observed without falling of the lid, the filaments distributed to the levator muscle not being affected.

The external strabismus and the immobility of the eyeball except in an outward direction are due to paralysis of the internal, superior, and inferior recti muscles, the external rectus acting without its antagonist. This condition requires no farther explanation. These points are illustrated by the experiment of dividing the nerve in rabbits. If the head of the animal be turned inward, exposing the eye to a bright light, the globe will turn outward, by the action of the external rectus; but if the head be turned outward, the globe remains motionless.

It is somewhat difficult to note the effects of paralysis of the inferior oblique muscle, which also is supplied by the third nerve. This muscle, acting from its origin at the inferior and internal part of the circumference of the base of the orbit, to its attachment at the inferior and external part of the posterior hemisphere of the eyeball, gives to the globe a movement of rotation on an oblique, horizontal axis, downward and backward, directing the pupil upward and outward. When this muscle is paralyzed, the superior oblique, having no antagonist, rotates the globe upward and inward, directing the pupil downward and outward. The action of the oblique muscles is observed when the head is moved alternately toward one shoulder and the other. In the human subject, when the inferior oblique muscle on one side is paralyzed, the eye can not move in a direction opposite to the movements of the head, as it does upon the sound side, so as to keep the pupil fixed, and the patient has double vision.

When all the muscles of the eyeball, except the external rectus and superior oblique, are paralyzed, as they are by section of the third nerve, the globe is slightly protruded, simply by the relaxation of most of its muscles. An opposite action is easily observed in a cat with the facial nerve divided so that it can not close the lids. When the cornea is touched, all of the muscles, particularly the four recti, act to draw the globe into the orbit, which allows the lid to fall slightly, and projects the little membrane which serves as a third eyelid in these animals.

The third nerve sends a filament to the ophthalmic ganglion of the sympathetic, and from this ganglion, the short ciliary nerves take their origin and pass to the iris. While it is undoubtedly true that division of the third nerve affects the movements of the iris, it becomes a question whether this be a direct influence or an influence exerted primarily upon the ganglion, not perhaps, differing from the general effects upon the sympathetic ganglia that follow destruction of their branches of communication with the motor nerves.

Herbert Mayo (1823) made experiments on thirty pigeons, living or just killed, upon the action of the optic, the third and the fifth nerves, on the iris. When the third nerves were divided in the cranial cavity in a living pigeon, the pupils became fully dilated and did not contract on the admission of intense light; and when the same nerves were pinched in the living or dead bird, the pupils were contracted for an instant on each stimulation of the nerves. The same results followed division or stimulation of the optic nerves, under similar conditions; but when the third nerves had been divided, no change in the pupil ensued upon stimulating the entire or divided optic nerves.

The third nerves animate the muscular fibres that contract the pupil, the contraction produced by stimulation of the optic nerves being reflex in its character. Longet divided the motor oculi and the optic nerve upon the right side. He found that stimulation of the central end of the divided optic nerve produced no movement of the pupil of the side upon which the motor oculi had been divided, but caused contraction of the iris upon the opposite side. This, taken in connection with the fact that in amaurosis affecting one eye, the iris upon the affected side will not contract under the stimulus of light applied to the same eye, but will act when the uninjured eye is exposed to the light, farther illustrates the reflex action which takes place through these nerves.

The reflex action by which the iris is contracted is not instantaneous, like most of the analogous phenomena observed in the cerebro-spinal system, and its operations are rather characteristic of the action of the sympathetic system and the non-striated muscular tissue. It has been found, also, by Bernard, in experiments upon rabbits, that the pupil is not immediately dilated after division of the third nerve. The method employed by Bernard, introducing a hook into the middle temporal fossa through the orbit and tearing the nerve, can hardly be accomplished without touching the ophthalmic branch of the fifth, which produces intense pain and is always followed by a more or less persistent contraction of the pupil. Several hours after the operation, however, the pupil is generally found dilated, and it may slowly contract when the eye is exposed to the light. In one experiment this occurred after the eye had been exposed for an hour. Farther experiments have shown that although the pupil contracts feebly and slowly under the stimulus of light after division of the motor oculi, it will dilate under the influence of belladonna and can be made to contract by operating upon other nerves. It is well known, for example, that division or stimulation of the fifth nerve produces contraction of the pupil. This takes place after as well as before division of the third nerve. Section of the sympathetic in the cervical region also contracts the pupil, and this occurs after paralysis of the motor oculi. These facts show that the third nerve is not the only one capable of acting upon the iris and that it is not the sole avenue for the transmission of reflex influences.

Bernard also found that stimulation of the motor oculi itself did not produce contraction of the pupil, but this result followed when he stimulated the ciliary nerves coming from the ophthalmic ganglion. Chauveau, in experiments upon horses, did not observe contraction of the pupil following stimulation of the motor oculi, although it was sometimes seen in rabbits. At all events, contraction is by no means constant; and when it occurs, it probably depends upon stimulation of the ciliary nerves themselves or irritation of the ophthalmic branch of the fifth, and not upon stimulation of the trunks of the third pair. When the eye is turned inward by a voluntary effort, the pupil is contracted; and when the axes of the two eyes are made to converge strongly, as in looking at near objects, the contraction is very considerable (Müller).

The third nerve contains filaments which preside over voluntary movements of the ciliary muscle in the accommodation of the eye to vision at different distances.

The following case illustrates, in the human subject, nearly all of the phenomena following paralysis of the motor oculi communis in experiments upon the lower animals:

The patient was a girl, nineteen years of age, with complete paralysis of the nerve upon the left side. There was slight protrusion of the eyeball, complete ptosis, with the pupil moderately dilated and insensible to ordinary impressions of light. The sight was not affected, but there was double vision, except when objects were placed before the eyes so that the axes were parallel, or when an object was seen with but one eye. The axis of the left eye was turned outward, but it was not possible to detect any deviation upward

or downward. Upon causing the patient to incline the head alternately to one shoulder and the other, it was evident that the affected eye did not rotate in the orbit but moved with the head. This seemed to be a case of complete and uncomplicated paralysis of the third nerve.

Patheticus, or Trochlearis (Fourth Nerve).

The physiology of the patheticus is very simple and resolves itself into the action of a single muscle, the superior oblique.

Physiological Anatomy.—The apparent origin of the patheticus is from the superior peduncles of the cerebellum; but it may be easily followed to the valve of Vieussens. The deep roots can be traced, passing from without inward, to the following parts: One filament is lost in the substance of the peduncles; other filaments pass from before backward into the valve of Vieussens and are lost, and a few pass into the frenulum; a few filaments pass backward and are lost in the corpora quadrigemina; but the greatest number pass to the median line and decussate with corresponding filaments from the opposite side. The fibres can be traced to a nucleus in the floor of the aqueduct of Sylvius, beneath the nucleus of the third nerve. The decussation of the fibres of origin of the fourth nerve has the same physiological significance as the decussation of the roots of the third. From this origin, the patheticus passes into the orbit, by the sphenoidal fissure, and is distributed to the superior oblique muscle of the eyeball. In the cavernous sinus it receives branches of communication from the ophthalmic branch of the fifth, but these are not closely united with the nerve. A small branch passes into the tentorium, and one joins the lachrymal nerve, these, however, being exclusively sensory and coming from the ophthalmic branch of the fifth. It also receives a few filaments from the sympathetic.

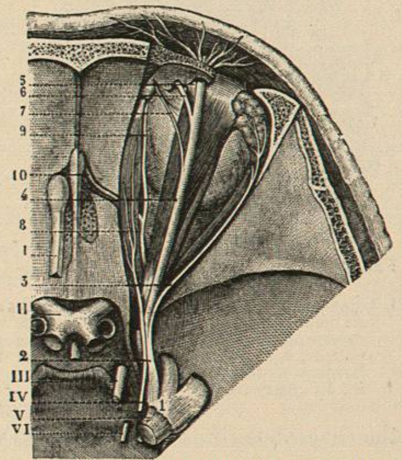

Fig. 195.—*Distribution of the patheticus* (Hirschfeld).

I, olfactory nerve; II, optic nerves; III, motor oculi communis; IV, *patheticus, by the side of the ophthalmic branch of the fifth, and passing to the superior oblique muscle*; VI, motor oculi externus; 1, ganglion of Gasser; 2, 3, 4, 5, 6, 7, 8, 9, 10, ophthalmic division of the fifth nerve, with its branches.

Properties and Uses of the Patheticus.—Direct observations upon the patheticus in living animals have shown that it is motor, and its stimulation excites contraction of the superior oblique muscle only. This muscle arises just above the inner margin of the optic foramen, passes forward, along the upper wall of the orbit at its inner angle, to a little, cartilaginous ring which serves as a pulley. From its origin to this point it is muscular. Its tendon becomes rounded just before it passes through the pulley, where it makes a sharp curve, passes outward and slightly backward, and becomes spread out to be attached to the globe, at the superior and external part of its posterior hemisphere. It acts upon the eyeball from the pulley at the upper and inner portion of the orbit as the fixed point and rotates the eye upon an oblique, horizontal axis, from below upward, from without inward and from behind forward. By its action, the pupil is directed downward and outward. It is the antagonist of the inferior oblique, the action of which has been described in connection with the motor oculi communis. When the patheticus is paralyzed, the eyeball is immovable, as far as rotation is concerned. When the head is moved toward the shoulder, the eye does not rotate to maintain the globe in the same relative position, and there is double vision.

Motor Oculi Externus, or Abducens (Sixth Nerve).

Like the patheticus, the motor oculi externus is distributed to but a single muscle. Its uses, therefore, are apparent from a study of its distribution and properties.

Physiological Anatomy.—The apparent origin of the sixth nerve is from the groove separating the anterior corpus pyramidale of the medulla oblongata from the pons Varolii, from the upper portion of the medulla and from the lower portion of the pons, next the groove. Its origin at this point is by two roots: an inferior, which is the larger and comes from the corpus pyramidale; and a superior root, sometimes wanting, which seems to come from the lower portion of the pons. All anatomists are agreed that the deep fibres of origin of this nerve pass to the gray matter in the floor of the fourth ventricle. Vulpian followed these fibres to within about two-fifths of an inch (10 mm.) of the median line, but they could not be traced beyond this point. It is not known that the fibres of the two sides decussate. From this origin the nerve passes into the orbit by the sphenoidal fissure and is distributed exclusively to the external rectus muscle of the eyeball. In the cavernous sinus it anastomoses with the sympathetic through the carotid plexus and receives a filament from Meckel's ganglion. It also receives sensory filaments from the ophthalmic branch of the fifth. It is thought by some anatomists that this nerve occasionally sends a small filament to the ophthalmic ganglion; and it was stated by Longet that this branch, which is exceptional, exists in those cases in which paralysis of the motor oculi communis, which usually furnishes all the motor filaments to this ganglion, is not attended with immobility of the iris.

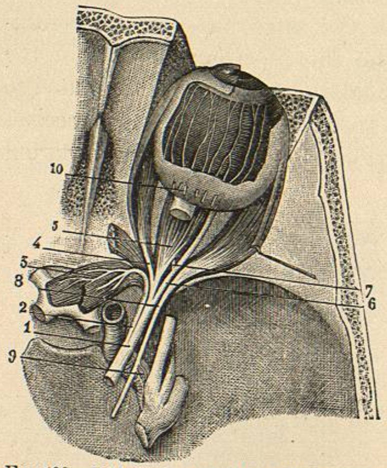

Fig. 196.—*Distribution of the motor oculi externus* (Hirschfeld).

1, trunk of the motor oculi communis, with its branches (2, 3, 4, 5, 6, 7); 8, *motor oculi externus, passing to the external rectus muscle*; 9, *filaments of the motor oculi externus, anastomosing with the sympathetic*; 10, ciliary nerves.

Properties and Uses of the Motor Oculi Externus.—Direct experiments have shown that the motor oculi externus is entirely insensible at its origin, its stimulation producing contraction of the external rectus muscle and no pain. The same experiments illustrate the action of the nerve, inasmuch as its stimulation is followed by contraction of the muscle and deviation of the eye outward. Division of the nerve in the lower animals or its paralysis in the human subject is attended with internal, or converging strabismus, due to the unopposed action of the internal rectus muscle.

With regard to the associated movements of the eyeball, it is important to note that all of the muscles of the eye which have a tendency to direct the pupil inward or to produce the simple movements upward and downward (the internal, inferior, and superior recti) are animated by a single nerve, the motor oculi communis, this nerve also supplying the inferior oblique; and that each of the two muscles that move the globe so as to direct the pupil outward, except the inferior oblique (the superior oblique and the external rectus), is supplied by a special nerve. The movements of the eyeball will be described more minutely in connection with the physiology of vision.

Nerve of Mastication (the Small, or Motor Root of the Fifth Nerve).

The motor root of the fifth nerve is entirely distinct from its sensory portion, until it emerges from the cranial cavity, by the foramen ovale. It is then closely united with the inferior maxillary branch of the large root; but at its origin it has been shown to be motor, and its section in the cranial cavity has demonstrated its distribution to a particular set of muscles.

Physiological Anatomy.—The apparent origin of the fifth nerve is from the lateral portion of the pons Varolii. The small, or motor root arises from a point a little higher and nearer the median line than the large root, from which it is separated by a few fibres of the white substance of the pons. At the point of apparent origin, the small root presents six to eight rounded filaments. If a thin layer of the pons covering these filaments be removed, the roots will be found penetrating its substance, becoming flattened, passing under the superior peduncles of the cerebellum and going to a gray nucleus, with large multipolar cells, in the anterior wall of the fourth ventricle, near the median line. At this point, the fibres change their direction, passing from without inward and from behind forward toward the median line, the fibres diverging rapidly. The posterior fibres pass to the median line, and certain of them decussate with fibres from the opposite side. The anterior fibres pass toward the aqueduct of Sylvius and are lost. The fibres become changed in their character when they are followed inward beyond the anterior wall of the fourth ventricle. Here they lose their white color, become gray and present a number of globules of gray substance between their filaments.

From the origin above described, the small root passes beneath the ganglion of Gasser—from which it sometimes, though not constantly, receives a filament of communication—lies behind the inferior maxillary branch of the large root, and passes out of the cranial cavity, by the foramen ovale. With-