Tutorial

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The Cranial Nerves

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Editor)

In contrast to typical spinal nerves, there is a great deal of variability in the functional constituents of cranial nerves. Whereas, a typical spinal nerve contains four functional types of neurons, a cranial nerve may contain as few as one or as many as five functional constituents. In other respects, cranial and spinal nerves have much in common, in that the cell bodies of motor neurons of both cranial and spinal nerves are located within the central nervous system (cranial nerve cell bodies in nuclei of the brain stem and spinal nerve cell bodies in ventral horns of the spinal cord) and, in most cases, the cell bodies of sensory neurons of both cranial and spinal nerves are located in ganglia outside the central nervous system.

It may be useful to review the functional constituents of both typical spinal nerves and cranial nerves. Those that comprise the spinal nerves are:

- 1) *General somatic efferents*, which innervate *striated somatic musculature* derived from the mesodermal domites.
- 2) *General visceral efferents*, which innervate *viscera, smooth muscles and salivary glands*.
- 3) *General somatic afferents*, which convey information from *somatic structures* to the central nervous system.
- 4) *General visceral afferents*, which project to the central nervous system from the *viscera*.

In addition to these four functional types of neurons, cranial nerves may contain three more components. They are:

- 5) *Special visceral efferents*, which innervate special visceral muscles which are derived from the branchial arches. Since the branchial arches are precursors of the neck, jaw, face and external ear, the associated musculature is innervated by these special efferents. The muscles include *muscles of the pharynx and larynx, muscles of facial expression and mastication*, as well as the *sternocleidomastoideus and trapezius muscles*.
- 6) *Special visceral afferents*, which subserve the modalities of *taste and olfaction*.
- 7) *Special somatic afferents*, which subserve the special senses of *hearing, equilibrium and vision*.

The functional organization in the brain stem is similar to that in the spinal cord; that is, afferent systems are associated with dorsal regions, and efferent systems are associated with ventral regions. Therefore, in general, the four functional afferent columns are located dorso-lateral to the sulcus limitans, and the three functional efferent columns are located ventro-medial to the sulcus limitans at brain stem levels. All of these functional columns receive fibers from the cerebral cortex via *corticobulbar fibers*, the origins and functions of which are the same as the corticospinal fibers. It is important to understand that the corticobulbar fibers project not only to the motor nuclei of cranial nerves, but also to sensory nuclei of cranial nerves. Their function parallels that of the corticospinal fibers which project to the dorsal column nuclei and the dorsal horns of the spinal cord, that is, to filter out information which is of no value to the cerebral cortex.

I. OLFACTORY NERVE

The cell bodies of the first order neurons in the olfactory system are located in the mucous membranes of the upper part of the nasal passages. The axons are very fine, unmyelinated *special visceral afferent*

fibers which project through the cribriform plates and terminate by synapsing with the second order neurons in the *olfactory bulbs*, which rest upon the cribriform plates. The fibers of the tract may or may not synapse again, and their primary projections are to the uncus, which is located on the posterior portion of the parahippocampal gyrus (olfactory cortex) and to the amygdaloid nucleus, which is located in the dorso-medial portion of the temporal lobe and is continuous with the uncus, which is just caudal to it.

There is no evidence to indicate that discrimination of odors is based upon structurally distinct types of receptors, but some evidence suggests that some odors may be distinguished by their relative effectiveness in stimulating specific regions of the olfactory epithelium.

The olfactory system is unique amongst the sensory systems in that it is the only system which does not relay through the thalamus en route to the cerebral cortex.

II. OPTIC NERVE

The visual receptors consist of the rods and cones of the retina, which is actually an outgrowth of the diencephalon. The cell bodies of the optic neurons are located in the *retinal ganglion cells*, and their axons exit from the retina at the optic disc. The axons subserving sight are myelinated *special somatic afferents*, which enter the skull as the optic nerve, via the optic foramina, and join to form the optic chiasm. In the optic chiasm, the *fibers which originate from the nasal hemiretina cross, but those which originate from the temporal hemiretina do not cross*. This partial decussation results in the left cerebral hemisphere seeing the right half of the visual field and the right cerebral hemisphere seeing the left half of the visual field (see Fig. 1).

With the pattern of these projections in mind one can determine whether a lesion is anterior or posterior to the optic chiasm. If the optic nerve is lesioned completely on one side anterior to the optic chiasm, there will be loss of vision on the side of the lesion. If the optic tract is le-

Figure 1. The arrangement of nerve fibers in the optic chiasm. The arrows indicate the direction in which the rays of light penetrate the lenses. The shaded nerve fibers from the left temporal hemiretina and the right nasal hemiretina carry information from the right visual field, and the unshaded fibers from the left nasal hemiretina and right temporal hemiretina carry information from the left visual field. Therefore, the right cerebral cortex sees the left visual field, and the left cerebral cortex sees the right visual field.

sioned unilaterally posterior to the optic chiasm, it will produce loss of vision of the visual field on the contralateral side (i.e., if the lesion is on the left, vision will be lost in the right half of the visual field and vice versa). Loss of vision which is restricted to a single visual field is called *homonymous hemianopsia*. It is not uncommon for a patient who has had a cerebral vascular accident to have concomitant involvement of the optic tract. In this case the patient may have a *contralateral* spastic hemiplegia or hemiparesis in combination with a *contralateral homonymous hemianopsia*.

Posterior to the optic chiasm, the optic neurons course posteriorly in the optic tracts and may terminate in one of three areas. They may:

- 1) Terminate in the *superior colliculus* where they participate in reflex arcs which involve movements of the neck region via the tecto-spinal tract and movements of the eyes via cranial nerve nuclei III, IV and VI.
- 2) Project to the *pretectal area*, which is just rostral to the superior colliculus. This projection provides the afferent link of the *pupillary light reflex*. Axons of the pretectal area project bilaterally to the *Edinger-Westphal nucleus*, which is part of the oculomotor nerve complex. Fibers from the Edinger-Westphal nucleus project to the ciliary ganglion and from there to

the smooth muscle of the sphincter of the iris, to complete the arc.

- 3) The largest component of the optic tract projects to the lateral geniculate nucleus of the thalamus, which is the last relay en route to the visual cortex. The visual cortex is located on either side of the calcarine fissure, thus the last portion of this tract is called the *geniculocalcarine tract*. Whereas the first two projections have to do with a variety of optic reflexes, the lateral geniculate nucleus receives fibers which are concerned with visual perception.

III. OCULOMOTOR NERVE

The cells of origin of the third nerve are located in the mesencephalon, ventral to the cerebral aqueduct at the level of the superior colliculus. It contains:

- 1) *General somatic efferents*, which supply all of the extraocular eye muscles except the lateral rectus and superior oblique muscles, plus the levator palpebrae superioris, which elevates the upper eyelid. These fibers leave the skull via the *superior orbital fissure*.
- 2) *General visceral efferents*. These are preganglionic parasympathetic fibers which arise specifically in the *Edinger-Westphal nucleus*, project to the ciliary ganglion and onto the sphincter of the iris, as described with the second cranial nerve, as to the efferent link of the pupillary light reflex. They function to *constrict* the pupils. If light is shown into one eye only, both pupils constrict because fibers from one optic tract project to the pretectal nuclei of both sides by way of the posterior commissure. Control of the pupillary dilatation is a function of the *superior cervical ganglion*.

There are also projections from the Edinger-Westphal nucleus which project to the ciliary muscles of the eye. These produce alterations in the shape of the lens so that the eye can accommodate to visualize objects at different distances.

Very recent evidence (C.B. Saper, N.D. Yamodis and A.D. Loewy, Abstracts-7th annual meeting of the Society for Neuroscience, November 6-10, 1977) indicates the Edinger-Westphal nucleus also projects to the medulla and spinal cord. The functional implications of these connections have not been explored, but we may have to start thinking of this nucleus as more than just a parasympathetic preganglionic nucleus as it

has traditionally been regarded.

Lesions of the third nerve may produce an ipsilateral lower motor neuron paralysis, with the following symptoms:

- 1) *External strabismus*, due to the unopposed action of the lateral rectus muscle.
- 2) Inability to move the eye vertically.
- 3) *Ptoxis* (drooping of the eyelid).
- 4) Loss of the pupillary light reflex.
- 5) Loss of the ability of the lens to accommodate.

Because of the proximity of the third nerves to the cerebral peduncles as they emerge from the midbrain, often both the corticospinal tracts and extrapyramidal tracts, along with the third nerve, are included in a single lesion. When such a lesion occurs, the result is an ipsilateral lower motor neuron paralysis of the muscles innervated by the third nerve, combined with a contralateral hemiplegia or hemiparesis.

IV. TROCHLEAR NERVE

The nucleus of the fourth nerve is also located in the mesencephalon just caudal to the nuclear complex of the third nerve, near the midline. This is the only one of the cranial nerves to emerge from the posterior aspect of the brain stem. After emerging from the nucleus, the fibers decussate in the superior medullary velum, curve around the lateral aspect of the brain stem and enter the cavernous sinus. After emerging from the cavernous sinuses, the nerves exit from the skull through the superior orbital fissures along with the third nerve and the ophthalmic divisions of the fifth cranial nerves. The fourth nerve contains *general somatic efferent* fibers which supply the *superior oblique muscles*.

Isolated lesions of the fourth nerve are rare, and when they do occur, symptoms are difficult to detect.

V. TRIGEMINAL NERVE

The fifth cranial nerve contains both motor and sensory components.

- 1) *General somatic afferents* convey:
 - a) exteroceptive impulses from
 1. the skin of the face and forehead,
 2. mucous membranes of the nose, nasal sinuses and mouth,
 3. teeth,
 4. extensive portions of the cranial dura mater.
 - b) proprioceptive impulses from
 1. muscles of the face,
 2. temporomandibular joint receptors.

- 2) *Special visceral efferents* control:
- a) muscles of mastication,
 - b) tensor tympani muscles,
 - c) tensor veli palatini muscles,
 - d) mylohyoid muscles,
 - e) anterior belly of the digastric muscles.

All of the *afferent* fibers of the trigeminal complex, except those subserving proprioception, have their cell bodies in the trigeminal (semilunar) ganglion, which is located on the petrous portion of the temporal bone. The peripheral processes enter the ganglion through the three divisions of the fifth nerve; the ophthalmic (enters the skull via the superior orbital fissure), the maxillary (enters the skull via the foramen rotundum) and mandibular nerve (enters the skull via the foramen ovale). The *ophthalmic* and *maxillary* divisions of the nerve both contain *only* sensory neurons, since the *entire* motor root is incorporated into the *mandibular* division, which is the sole nerve supply of the muscles of mastication.

The central processes of the sensory neurons which have their cell bodies located in the trigeminal ganglion enter the brain stem at the level of the pons. They then terminate in one of two nuclei. Some of them ascend for a short distance to terminate in the principle sensory nucleus of nerve V. The fibers that terminate in the principle sensory nucleus primarily subserve the modalities of *touch*, *pressure* and *two-point discrimination*. Some of the sensory fibers descend for long distances to form the *spinal trigeminal tract* which, along with its nucleus, extends from upper cervical segments to the point of entry of the fifth nerve into the pons. The modalities of *pain* and *thermal sense* are handled exclusively by this part of the trigeminal complex. There is also some representation of proprioception from the extraocular muscles located in the rostral part of the spinal nucleus of V. Fibers that enter the spinal tract of nerve V terminate at all levels of the spinal nucleus. The spinal trigeminal nucleus also receives fibers subserving pain and temperature from cranial nerves VII, IX and X, as well as from corticobulbar tracts. The spinal tract is somatotopically organized, with fibers from the ophthalmic division in a ventral position, those from the mandibular division in a dorsal position and those from the maxillary division in an intermediate position.

The mesencephalic nucleus of the fifth nerve consists of very large cells

that appear to represent dorsal root ganglion cells in the central nervous system. (This is an exception to the rule that nerve cell bodies of sensory neurons are located outside the central nervous system.) This nucleus, as its name implies, is located in the caudal portion of the mesencephalon. It receives impulses from proprioceptors located in the muscles of mastication and facial expression and may be thought of as the homologue of Clarke's column for the face area. Afferents to this nucleus are only found in the *mandibular* division of the fifth nerve and are probably concerned with reflex control of the force of biting.

The fibers which originate in the *motor nucleus* of the fifth nerve emerge from the pons along with the sensory portions of the nerve, but they do not enter the trigeminal ganglion. Instead, they bypass the ganglion by coursing inferior to it and then become incorporated into the mandibular division. The motor portion accompanies the sensory portion of the mandibular nerve through the

foramen ovale but then diverges from the sensory portion to innervate the muscles of mastication in addition to several other muscles mentioned previously. The motor nucleus receives afferents from all three of the sensory nuclei of the fifth nerve complex. The projections from the mesencephalic nucleus provide an arc for reflex control of the muscles of mastication in response to stretch and/or contraction of those muscles. Fibers which project to the motor nucleus from the principle sensory nucleus and the spinal nucleus provide reflex control of the muscles of mastication in response to stimulation of superficial receptors. The motor nucleus also receives crossed projections from the cerebral cortex so that the musculature of the jaw is under direct cortical control.

The *principle sensory* and *spinal trigeminal* nuclei both project ipsilaterally to the motor nuclei of cranial nerves VII and XII and provide the afferent limb of reflexes associated with the muscles of the tongue (efferent link is via nerve XII)

Figure 2. The central nuclei of the trigeminal complex. 1 = the ophthalmic division, 2 = the maxillary division, 3 = the mandibular division. The arrow indicates the level at which trigeminal tractotomy may be done for relief of pain from trigeminal neuralgia. In this procedure the neurons which convey the modalities of pain and thermal sense to the spinal nucleus are cut without interruption of the other neurons of the system.

in response to stimulation of superficial receptors in the distribution of nerve V. In addition, the principle sensory and spinal nuclei both send projections to the contralateral medial lemniscus, thus providing the head for the headless man represented in the dorsal column system. These fibers then project, along with the dorsal column system, to the ventrobasal complex of the thalamus and on to the somatosensory cortex. The modalities of pain and temperature from the seventh, ninth and tenth cranial nerves accompany these fibers en route to the cerebral cortex. The spinal trigeminal nucleus also sends projections to the reticular formation.

The central projections of the *mesencephalic nucleus* are obscure, but it is reasonable to assume that by some pathway they terminate in the cerebellum, since other pathways subserving subconscious proprioception terminate there.

Irritation of the fifth nerve, which is called *trigeminal neuralgia* or *tic douloureux*, is a condition sometimes encountered clinically. This is a condition in which there is excruciating pain over the distribution of part of or the entire nerve. If the pain is intractable, surgery may be indicated. There are several surgical procedures now being utilized, but one of them, called *trigeminal tractotomy*, serves well to emphasize the anatomy of the spinal tract in the brain stem at the level of the obex of the fourth ventricle, where the tract is located very superficially. The pain is thus eliminated, or at least reduced without eliminating other qualities of sensation to any extent. Fig. 2 illustrates the relationships of the central nuclei of the trigeminal nuclei to each other and the location at which trigeminal tractotomy may be done.

VI. ABDUCENS NERVE

The abducens nerve nucleus is located in the floor of the fourth ventricle, deep to the facial colliculus at the level of the pons. It emerges from the brain at the caudal level of the pons and, after a long intracranial course, exists the skull via the superior orbital fissure to innervate the *lateral rectus muscle*. The sixth nerve contains only *general somatic efferent* fibers, since the lateral rectus muscle is the sole structure which it innervates.

The nucleus receives crossed and uncrossed fibers from the vestibular nuclei via the medial longitudinal fasciculus and is, therefore, involved with vestibular control of eye movements, as are nerves III and IV.

It also receives bilateral projections from the cerebral cortex by way of the corticobulbar tracts.

Because this nerve has a very long intracranial course, it is subject to trauma, especially when there is an increase in intracranial pressure. The symptoms of sixth nerve involvement are medial deviation of the eye due to weakness of the lateral rectus muscle, which leads to *diplopia* (double vision). As the fibers from the sixth nerve emerge from the pons, they are in very close approximation to the corticospinal and extrapyramidal tracts so that often a lesion will involve both systems. The result is an ipsilateral lower motor neuron paralysis of the lateral rectus muscle combined with a contralateral hemiplegia or hemiparesis.

VII. FACIAL NERVE

The facial nerve contains several functional components:

- 1) *General somatic afferents* from the posterior auricular nerve supply the skin posterior to the ear and the external meatus along with nerves IX and X. These fibers are contained in the nervus intermedius and terminate in the spinal trigeminal nucleus. They provide the afferent limb of a reflex arc which produces responses in the muscles of mastication to cutaneous stimulation. The efferent limb of the reflex is provided by projections from the spinal trigeminal nucleus to the motor nucleus of the fifth nerve, from whence efferent fibers reach the muscles of mastication by way of the mandibular division of the fifth nerve.
- 2) *Special visceral afferents*, which

subserve taste on the anterior two-thirds of the tongue, are contained in the *chorda tympani* branch of the facial nerve. The nerve enters the stylomastoid foramen along with the general somatic afferents of the seventh nerve and, after synapsing in the geniculate ganglion, enters the middle cranial fossa via the internal acoustic meatus along with the remainder of the facial nerve and the vestibulocochlear nerve. The fibers then project to the tractus solitarius and terminate in the nucleus solitarius. From there, fibers project to the ventro-basal complex of the thalamus, and the last order neurons project to the cerebral cortex.

- 3) *Special visceral efferents* supply the muscles of facial expression, stapedius muscle, the posterior belly of the digastric muscle and the stylohyoid muscle. These neurons arise from the motor nucleus of the seventh nerve at the level of the pons and emerge from the brain at the caudal level of the pons after taking a tortuous course dorsally between the abducens nucleus and the floor of the fourth ventricle (see Fig. 3).
- 4) *General visceral efferents* arise from the superior salivatory nucleus, which is continuous caudally with the nucleus ambiguus. They are preganglionic parasympathetic fibers which, after synapsing in peripheral ganglia, supply the submaxillary, sublingual and lacrimal glands.

The facial motor nucleus receives projections from a number of sources, one of which is the spinal trigeminal

Figure 3. The nuclei associated with the facial nerve.

Figure 4. The corticobulbar projections to the motor nucleus of the facial nerve. Shaded area controls muscles of the upper one-third of the face. Dotted area controls the muscles of the lower two-thirds of the face.

nucleus. Sensory fibers of the trigeminal nerve provide the afferent link of a reflex arc of which the special visceral efferent fibers of the facial nerve supply the afferent link to provide for corneal and trigeminal facial reflexes. In addition, the nucleus receives fibers from the corticobulbar system, the rubrobulbar system and presumably from the mesencephalic reticular formation and the auditory and visual systems. Projections from the auditory system probably mediate certain acoustico-facial reflexes, such as closing one's eyes in response to loud noises. Those from the visual system produce squinting in response to bright light.

The control of the facial musculature by the cerebral cortex is different in different regions of the face. The muscles of the upper one-third of the face are innervated by a part of the facial motor nucleus which is controlled bilaterally by the cortex, while those of the lower two-thirds are innervated by a part of the nucleus which is controlled by the contralateral hemisphere of the cerebral cortex only (see Fig. 4). This is important clinically. If the corticobulbar projections to the motor nucleus of the seventh nerve are damaged unilaterally, there will be little or no weakness of the muscles of the upper one-third of the face, but there will be a contralateral paralysis of the muscles of the lower two-thirds of the face. This condition is called *Bell's Palsy*. Accompanying such a lesion there may also be a disturbance of the ability to taste and of glandular secretory function. Occasionally in such cases, aberrant regrowth of the parasympathetic fibers may result in tearing in response to a salivary stimulus (crocodile tears) or in salivation in response to an emotional stimulus.

If the facial nerve is damaged external to the motor nucleus of nerve VII,

all muscles on the ipsilateral side will be paralyzed.

VIII. VESTIBULOCOCHLEAR NERVE

The eighth nerve, as its name states, consists of two parts, both of which contain only *special somatic afferent* fibers. The cochlear division conveys auditory impulses from the cochlea, and the vestibular division conveys impulses from the utricle, saccule and semicircular canals.

Cochlear division

The fibers of the cochlear nerve originate within the *spiral ganglion* of the cochlea and from there project to the dorsal and ventral cochlear nuclei, which are located on the external surface of the inferior cerebellar peduncle, are the first relay stations in the auditory system. Both of these nuclei contain complete *tonotopic organization*, that is, they both receive the entire spectrum of frequencies, from the highest frequencies, projected from the basilar part of the cochlea, to the lowest frequencies, projected from the apical portion of the cochlea. From the cochlear nuclei, some fibers enter the *ipsilateral superior olive* or *lateral lemniscus*, or cross to the *contralateral superior olive* or *lateral lemniscus* and ascend to the *inferior colliculi bilaterally*. From the inferior colliculus, fibers are relayed to the *medial geniculate nucleus* and on to the *auditory cortex in the temporal lobe*. It should be emphasized that auditory representation is bilateral, since some fibers cross and some do not, en route to the cortex. Therefore, loss of hearing in one ear indicates a peripheral lesion, and loss of hearing in both ears indicates a central lesion. The symptom of cochlear nerve lesions is buzzing or ringing in the ears (tinnitus), which usually precedes a diminution in hearing.

Vestibular division

The vestibular nerve is concerned with orientation of the head in three-dimensional space and with equilibrium. The cell bodies are located in *Scarpa's ganglion*, which lies in the *internal acoustic meatus*. Impulses from the utricle, saccule and semicircular canals reach the four vestibular nuclei, but some impulses go directly to the *ipsilateral cerebellum* by way of the *inferior cerebellar peduncle*.

From the vestibular nuclei, fibers project to the cerebellum, medial longitudinal fasciculus and to the spinal cord, via the vestibulo-spinal tract (arises from Deiter's nucleus). There are also important reciprocal connections between the cerebellum

and the vestibular nuclei, and between the reticular formation and vestibular nuclei. The connections with the reticular formation are responsible for the vomiting and cardiovascular reactions associated with Meniere's disease. In addition, the vestibular nuclei project to the contralateral cerebral cortex close to the area in which the face is represented in SMI. The exact location of the pathway is not known, but it is responsible for conscious knowledge of spatial orientation.

The vestibular nuclei play an important role in cerebellar mechanisms and in control of movement by way of the medial longitudinal fasciculus, which projects to cervical spinal cord levels, as well as to cranial nerves III, IV, and VI and by way of the vestibulo-spinal tracts, which project to all levels of the spinal cord.

If the vestibular nerve is damaged, the symptoms are:

- 1) vertigo (dizziness), which may result in nausea and vomiting,
- 2) nystagmus (horizontal, vertical or rotary rhythmic movements of the eye, with a fast and slow component),
- 3) a tendency to fall toward the abnormal side.

Within the substance of the brain stem the cochlear and vestibular divisions are separated so that a lesion could affect one of the divisions selectively. However, in the internal acoustic meatus, both divisions course together, along with the seventh nerve, so that a lesion in that area could involve both divisions of the eighth nerve, along with the seventh nerve.

IX. GLOSSOPHARYNGEAL NERVE

The ninth nerve contains both afferent and efferent fibers and emerges from the skull at the jugular foramen. It contains several functional components.

- 1) *General somatic afferents* supply the skin posterior to the ear and the external acoustic meatus via the posterior anticular nerve in common with nerves VII and X. The cell bodies of these fibers are located in the *superior ganglion* of the ninth nerve, located within the *jugular foramen*. From the superior ganglion the axons project to the *tract and nucleus of spinal V* and the pathway terminates in the *somato-sensory cortex* after relaying through the *ventro-basal complex of the thalamus*.
- 2) *Special visceral afferent fibers* subserve taste on the posterior

one-third of the tongue. These fibers terminate in the *nucleus solitarius* along with the gustatory fibers of nerves VII and X. Through pathways that are not well established, these fibers terminate in the cerebral cortex after synapsing in the thalamus.

- 3) *General visceral afferent fibers* convey touch, pain and temperature senses from the mucous membranes of the posterior portion of the tongue, tonsils and the eustachian tubes. Their cell bodies are located in the *inferior ganglion* of the ninth nerve, located in the *petrous portion of the temporal bone*. Presumably, these fibers terminate in the *nucleus of spinal V* and the pathway joins the *medial lemniscus* as do other fibers which terminate in that nucleus.

There is also a special sensory branch of the ninth nerve from the carotid sinus which is located at the bifurcation of the common carotid artery into internal and external carotid arteries. Impulses are sent to the *dorsal motor nucleus of the vagus* in the medulla. The efferent link of the reflex arc consists of vagal fibers which terminate in the sinoatrial and atrioventricular nodes as well as in atrial muscle fibers. The effective stimulus for impulse transmission in the ninth nerve is an increase in blood pressure. Through this reflex arc, the tenth nerve reduces both heart rate and blood pressure.

- 4) *General visceral efferent fibers* originate in the *inferior salivatory nucleus* of the medulla. These fibers are responsible for secretory activity in the parotid gland.
- 5) *Special visceral efferent fibers* originate in the *nucleus ambiguus* and innervate the stylopharyngeus muscle, which elevates the pharynx in swallowing and speech. Selective lesions of the ninth nerve are rare, but when they do occur, the following symptoms may be produced:
 - 1) loss of the gag reflex,
 - 2) loss of the carotid sinus reflex,
 - 3) loss of taste on the posterior one-third of the tongue,
 - 4) excruciating pain over the sensory distribution of the nerve.

X. Vagus Nerve

The vagus nerve accompanies the glossopharyngeal and spinal accessory nerves through the jugular foramen and also contains several afferent and efferent components. They are:

- 1) *General somatic afferents* by way

of the posterior auricular nerve, which distributes in common with nerves VII and IX. The central pathways are the same as those described for nerves VII and IX.

- 2) *General visceral afferent fibers* from the pharynx, larynx, trachea, esophagus and thoracic and abdominal viscera. These fibers project to the caudal portion of *nucleus solitarius* and from there some fibers terminate in the *reticular formation* of the medulla, where they function in the central regulation of respiratory, cardiovascular and emetic activities. Other fibers terminate on the *motor nuclei of cranial nerves VII and IX* for control of lingual and secretory functions.
- 3) *Special visceral afferent fibers* from taste buds on the epiglottis project to the *nucleus solitarius* as do gustatory neurons from the seventh and ninth cranial nerves. The ensuing pathways to the ventral basal nucleus of the thalamus and the cerebral cortex are as described for the seventh and ninth nerves.
- 4) *General visceral efferent fibers* are preganglionic parasympathetic neurons which innervate all thoracic and visceral structures as far inferior as the point where the transverse and descending colons meet. Structures inferior to that level are innervated by parasympathetic fibers from spinal nerves S2, 3 and 4. The preganglionic parasympathetic fibers of the vagus nerve originate in the *dorsal nucleus of the vagus*, located in the floor of the fourth ventricle.
- 5) *Special visceral efferent fibers* originate in the *nucleus ambiguus* and innervate the muscles of the larynx and the pharynx.

If the tenth nerve is destroyed bilaterally, death follows very rapidly due to loss of the respiratory reflexes and uncontrolled cardiac acceleration, accompanied by complete laryngeal paralysis. If the tenth nerve is damaged unilaterally, the most common symptoms are deviation of the soft palate and uvula to the normal side, hoarseness due to weakness in the laryngeal muscles and dysphagia (difficulty with swallowing) due to weakness of the pharyngeal constrictors.

XI. Spinal Accessory Nerve

The eleventh nerve is divided into cranial and spinal components. The *cranial root* contains *special visceral efferent* fibers of which the cell bodies are located in the *nucleus ambiguus*.

From their origin there, they join the vagus nerve to innervate the *intrinsic muscles of the larynx*. The *spinal root* originates in the anterior horns of spinal segments extending rostrally from the pyramidal decussation to as far caudally as cervical segments five or six.

The cranial portion of the nerve exists from the medulla posterior to the inferior olive as do nerves nine and ten. The spinal portion enters the skull via the *foramen magnum*, joins the cranial portion and both parts leave the skull via the *jugular foramen*. The spinal portion of the nerve innervates the *sternocleidomastoideus* and *trapezius* muscles.

The eleventh nerve receives projections from the medial longitudinal fasciculus and other systems involved with eye-head-neck coordination as well as from the cerebral cortex via corticobulbar fibers.

The major symptoms produced by lesions of the nerve are weakness in rotation of the head to the opposite side (*sternocleidomastoideus* muscle) and in shoulder girdle elevation and retraction (*trapezius* muscle).

XII. Hypoglossal Nerve

The twelfth nerve is only known to contain *general somatic efferent fibers*, although it may contain some general somatic afferent fibers which innervate muscle spindles of the tongue. The general somatic efferent originate in the *hypoglossal nuclei*, which are located in the medial portion of the caudal end of the fourth ventricle. The fibers emerge from the medulla in the *antero-lateral sulcus* anterior to the inferior olive. They exit from the skull by way of the *hypoglossal canal*.

The hypoglossal nucleus receives projections from the reticular formation, corticobulbar fibers and from nerves V, IX and X, which mediate reflex tongue movements in response to stimulation of the mucous membranes of the lingual, oral and pharyngeal areas. It also receives some afferent fibers from visceral centers.

Unilateral lesions of the twelfth nerve produce a lower motor neuron paralysis of the ipsilateral one-half of the tongue, which includes loss of tone and movement as well as atrophy. When the tongue is protruded it deviates to the weak side due to inactivity of the *genioglossus* muscle on that side (see Fig. 5). The root of the twelfth nerve emerges in close association with the corticospinal tracts and thus, both may be involved

Figure 5. Inferior view of the tongue. A—illustrates the normal resting position of the tongue within the mouth (shaded area). When the tongue is protruded, there is no deviation to the right or to the left because the medial pulls of the left and right genioglossus muscles offset each other. The protruded tongue is indicated by the dotted areas in both A and B. In B the hypoglossal nerve has been damaged on the right side so that the right genioglossal muscle is not functioning. The left genioglossal muscle exerts an unopposed medial pull as it shortens toward the symphysis menti of the mandible and, therefore, the tongue deviates to the weak side as it is protruded. In A the arrows indicate the directions of pull of the intact left genioglossus only.

in a common lesion. Ipsilateral weakness of the tongue with a contralateral hemiplegia or hemiparesis may then be produced.

If the cortico-bulbar fibers which project to the hypoglossal nucleus are damaged, an upper motor neuron paralysis of the contralateral side of the tongue may be produced, since the cortico-bulbar fibers which control that nucleus are crossed.

The following table summarizes the functional constituents of the cranial nerves:

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