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chapter 9

Cranial and Autonomic Nerves

I. CRANIAL NERVES (Figure 9.1; Tables 9.1 to 9.3)

- Are 12 pairs of nerves that leave the CNS to pass through the bones of the skull. Most cranial nerves are connected to the brain stem, and all but one (vagus nerve, CN X) are distributed only in the head and the neck.
- Most cranial nerves emerge either from the ventral aspect of the brainstem (CN III, VI, XII) or laterally (CN V, VII, VIII, IX, X, XI). The only nerve to leave the dorsal surface of the brain stem is the trochlear nerve (CN IV), which arises from the dorsal aspect of the midbrain.
- Functional components in the cranial nerves.
- Most cranial nerves have only one function. Only two cranial nerves have two functions (CN III and CN V), and three cranial nerves have more than two functions (CN VII, IX, X). The three cranial nerves with more than two functions will be found to have the same five functions and can be described in a very similar way.

A. Olfactory Nerves (CN I) (Figure 9.1)

- Consist of approximately 20 bundles of unmyelinated afferent fibers (special visceral afferent [SVA]) that arise from neurons in the olfactory area, the upper one-third of the nasal mucosa, and mediate the sense of smell (olfaction).
- They pass through the foramina in the **cribriform plate** of the ethmoid bone and synapse in the **olfactory bulb**.

CLINICAL CORRELATES

Lesion of the olfactory nerve may occur as a result of ethmoidal bone fracture and cause **anosmia**, or loss of olfactory sensation. Many people with anosmia may complain of loss or alteration of taste since these senses are connected. Also, one may have a runny nose from CSF loss from fracture of the ethmoid bone.

B. Optic Nerve (CN II) (Figure 9.1)

- Is formed by the axons of **ganglion cells of the retina**, which converge at the optic disk.
- These fibers of the optic nerve are covered by a membrane continuous with the dura, and the myelin of the optic nerves is formed by oligodendroglia, just like CNS tracts.
- These nerves carry afferent fibers for vision (special somatic afferent [SSA]) from the retina to brain.

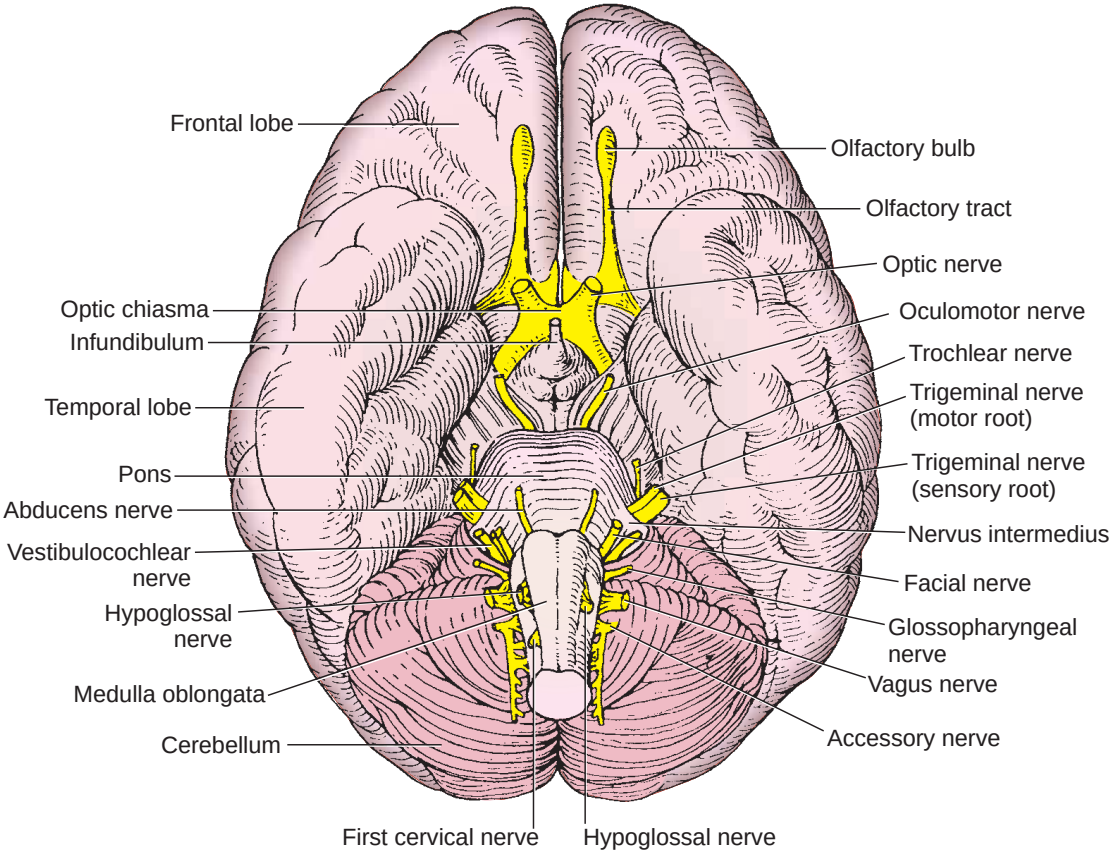

FIGURE 9.1. Cranial nerves on the base of the brain.

table 9.1 Cranial Nerves

Nerve	Cranial Exit	Cell Bodies	Components	Chief Functions
CN I: Olfactory	Cribriform plate	Nasal mucosa	SVA	Smell
CN II: Optic	Optic canal	Ganglion cells of retina	SSA	Vision
CN III: Oculomotor	Superior orbital fissure	Nucleus CN III (midbrain)	GSE	Eye movements (superior, inferior, and medial recti, inferior oblique, and levator palpebrae superioris Müller muscle)
		Edinger–Westphal nucleus (midbrain)	GVE	Constriction of pupil (sphincter pupillae muscle) and accommodation (ciliary muscle)
CN IV: Trochlear	Superior orbital fissure	Nucleus CN IV (midbrain)	GSE	Eye movements (superior oblique muscle)
CN V: Trigeminal	Superior orbital fissure; foramen rotundum and foramen ovale	Motor nucleus CN V (pons)	SVE	Muscles of mastication, mylohyoid, anterior belly of digastric, tensor veli palatini, and tensor tympani muscles
		Trigeminal ganglion	GSA	Sensation on head (skin and mucous membranes of face and head)
CN VI: Abducens	Superior orbital fissure	Nucleus CN VI (pons)	GSE	Eye movement (lateral rectus muscle)
CN VII: Facial	Stylomastoid foramen	Motor nucleus CN VII (pons)	SVE	Muscle of facial expression, posterior belly of digastric, stylohyoid, and stapedius muscles
		Superior salivatory nucleus (pons)	GVE	Lacrimal and salivary secretion
		Geniculate ganglion	SVA	Taste from anterior two-thirds of tongue and palate

table 9.1 Cranial Nerves *(continued)*

Nerve	Cranial Exit	Cell Bodies	Components	Chief Functions
		Geniculate ganglion	GVA	Sensation from palate
		Geniculate ganglion	GSA	Auricle and external acoustic meatus
CN VIII: Vestibulocochlear	Does not leave skull	Vestibular ganglion	SSA	Equilibrium
		Spiral ganglion	SSA	Hearing
CN IX: Glossopharyngeal	Jugular foramen	Nucleus ambiguus (medulla)	SVE	Elevation of pharynx (stylopharyngeus muscle)
		Inferior salivary nucleus (medulla)	GVE	Secretion of saliva (parotid gland)
		Inferior ganglion	GVA	Carotid sinus and body, tongue, pharynx, and middle ear
		Inferior ganglion	SVA	Taste from posterior one-third of tongue
		Superior ganglion	GSA	External ear
CN X: Vagus	Jugular foramen	Nucleus ambiguus (medulla)	SVE	Muscles of pharynx, larynx, and palate
		Dorsal nucleus (medulla)	GVE	Smooth muscles and glands in thoracic and abdominal viscera
		Inferior ganglion	GVA	Sensation in lower pharynx, larynx, trachea, and other viscerae
		Inferior ganglion	SVA	Taste on epiglottis
		Superior ganglion	GSA	Auricle and external acoustic meatus
CN XI: Accessory	Jugular foramen	Spinal cord (cervical)	SVE, GSE, or mixed	Sternocleidomastoid and trapezius muscles
CN XII: Hypoglossal	Hypoglossal canal	Nucleus CN XII (medulla)	GSE	Muscles of movements of tongue

GSA, general somatic afferent; GSE, general somatic efferent; GVA, general visceral afferent; GVE, general visceral efferent; SSA, special somatic afferent; SVA, special visceral afferent; SVE, special visceral efferent.

table 9.2 Functional Components in the Cranial Nerves

Functional Component	Type of Information Carried	Present in These Cranial Nerves
GSA	Pain, temperature, touch, proprioception	CN V, CN VII, CN IX, CN X
GSE	Motor to skeletal muscle of the eye and tongue	CN III, CN IV, CN VI, CN XII
GVA	Sensory from visceral organs	CN VII, CN IX, CN X
GVE	Autonomic motor fibers to smooth muscle, cardiac muscle, glands	CN III, CN VII, CN IX, CN X
SSA	Vision, hearing, equilibrium	CN II, CN VIII
SVA	Smell and taste	CN I, CN VII, CN IX, CN X
SVE or branchial efferent	Motor to skeletal muscles for mastication, facial expression, movement of the pharynx and larynx	CN V, CN VII, CN IX, CN X, CN XI (SVE, GSE, or mixed)

GSA, general somatic afferent; GSE, general somatic efferent; GVA, general visceral afferent; GVE, general visceral efferent; SSA, special somatic afferent; SVA, special visceral afferent; SVE, special visceral efferent.

- CN II leaves the middle cranial fossa to enter the orbit through the optic canal. The **optic chiasma** contains fibers from the nasal retina that cross over to the opposite side of the brain. The fibers from the temporal retina pass ipsilaterally through the chiasma.
- Mediates the afferent limb of the **pupillary light reflex**, whereas parasympathetic fibers in the oculomotor nerve mediate the efferent limb.

table 9.3 Lesion of Cranial Nerves

Nerve	Effects of Nerve Injury	Lesion Site and Cause
CN I: Olfactory nerve	Loss of smell (anosmia)	Fracture of cribriform plate
CN II: Optic nerve	Blindness; loss of afferent limb of pupillary light reflex	Fracture of orbit; lesion of optic pathway
CN III: Oculomotor nerve	Dilated pupil; ptosis; loss of accommodation and efferent limb of pupillary reflex; diplopia (double vision); external strabismus; downward and lateral gage deviation	Cavernous sinus thrombosis; midbrain lesion; aneurysm of posterior cerebral and superior cerebellar arteries
CN IV: Trochlear nerve	Inability to turn eye inferolaterally; trouble going downstairs	Cavernous sinus thrombosis; fracture of orbit; severe head injury
CN V: Trigeminal nerve	Sensory loss on face; loss of mastication; jaw deviation toward lesion side; loss of afferent limb of corneal and sneeze reflexes	Lesion of pons; fracture or tumor in region of trigeminal ganglion
CN VI: Abducens nerve	Diplopia; inability to abduct eye; internal strabismus	Cavernous sinus thrombosis; brain stem lesion; fracture of orbit
CN VII: Facial nerve	Facial paralysis (Bell palsy); loss of efferent limb of corneal reflex; loss of taste to anterior two-thirds of tongue; loss of secretion of lacrimal, submandibular, sublingual, nasal and palatine glands	Lesion of pons; Injury to internal auditory meatus; laceration in parotid region; fracture of temporal bone; inflammation in facial canal
CN VIII: Vestibulocochlear nerve	Loss of hearing and balance	Tumor in internal auditory meatus and at cerebellopontine angle
CN IX: Glossopharyngeal nerve	Loss of taste to posterior one-third of tongue; loss of receptors in carotid body and sinus; loss of parotid gland secretion; paralysis of stylopharyngeus muscle; loss of afferent limb of gag reflex	Brain stem lesion; penetrating neck injury
CN X: Vagus nerve	Deviation of uvula toward normal side; vocal cord paralysis; paralysis of palate, pharynx, and larynx; loss of receptors in aortic body and arch; loss of efferent limbs of gag and sneeze reflexes and both limbs of cough reflex	Brain stem lesion; penetrating neck injury; skull base fracture
CN XI: Accessary nerve	Inability to shrug shoulder; difficulty in turning head to opposite side	Penetrating injury to posterior cervical triangle; skull base fracture
CN XII: Hypoglossal nerve	Loss of tongue movements; tongue deviation toward lesion side	Deep laceration of neck and basal skull fracture
Sympathetics to head	Horner syndrome: constricted pupil (miosis); ptosis; enophthaloms; anhidrosis; vasodilation (flushing face)	Lesion of cervical sympathetic nerves; deep laceration of neck

CLINICAL CORRELATES

Lesion of the optic nerve (optic neuritis) may be caused by inflammatory, degenerative, demyelinating, or toxic disorders and may result in **blindness** or diminished visual acuity and **no pupillary light reflex** in the effected eye. A lesion of the **optic chiasma** due to a pituitary tumor produces bitemporal hemianopsia or tunnel vision. A lesion of the **optic tract** produces a loss of the opposite visual field, a contralateral homonymous hemianopsia.

C. Oculomotor Nerve (CN III) (Figure 9.2)

- Enters the orbit through the superior orbital fissure within the tendinous ring.
- Supplies efferent fibers (general somatic efferent [GSE]) for contraction of the extraocular muscles (i.e., medial, superior, and inferior recti; inferior oblique; and levator palpebrae superioris).
- It also contains preganglionic parasympathetic fibers from neuronal cell bodies located in the Edinger–Westphal nucleus that supply the ciliary ganglion. Postganglionic fibers derived from the ciliary ganglion run in the **short ciliary nerves** to supply the **sphincter pupillae** (miosis) and the **ciliary smooth muscle** (accommodation/near vision).
- These parasympathetic fibers mediate the efferent limb of the pupillary light reflex.

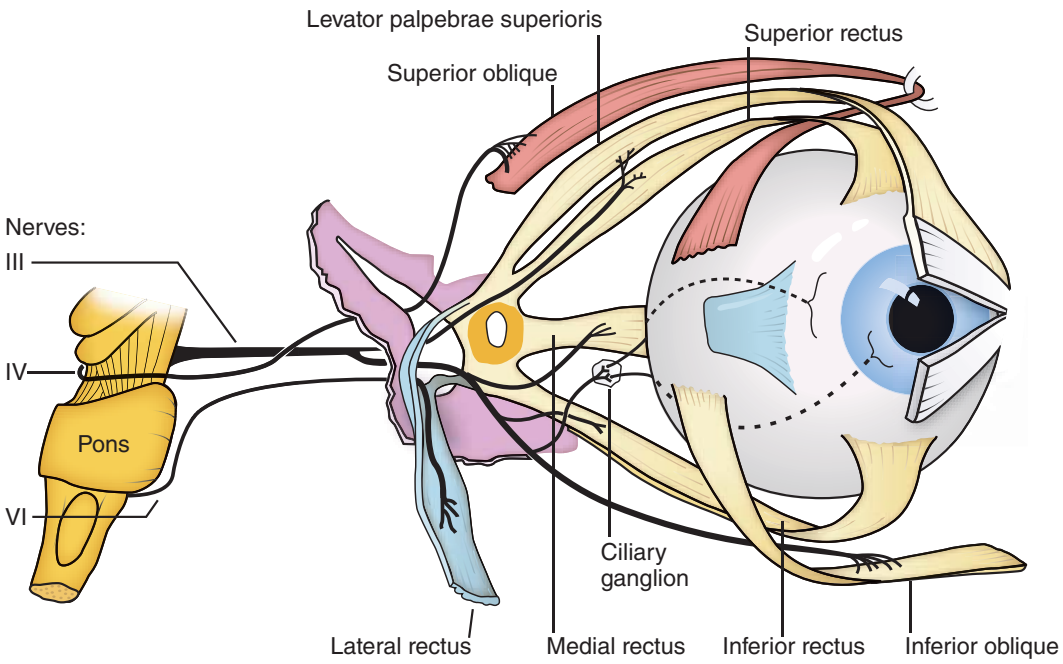

FIGURE 9.2. Distribution of the oculomotor, trochlear, and abducens nerves.

CLINICAL CORRELATES

Lesion of oculomotor nerve causes paralysis of the levator palpebrae superioris (**ptosis**), paralysis of the medial rectus (**external strabismus**), paralysis of sphincter pupillae, resulting in **dilation of the pupil** (mydriasis is the result of unopposed sympathetic supply to the dilator papillae muscles), and paralysis of ciliary muscles, resulting in **loss of accommodation** (near vision) because of damage to the preganglionic parasympathetic fibers. Lesion also causes **loss of pupillary light reflex** because of damage to parasympathetic fibers that mediate the efferent limb of the pupillary light reflex.

D. Trochlear Nerve (CN IV) (Figure 9.2)

- Passes through the lateral wall of the cavernous sinus in the middle cranial fossa and enters the orbit by passing through the superior orbital fissure.
- Motor fibers (GSE) supply the superior oblique muscle.
- This is the **smallest** of all **cranial nerves** and the only CN that emerges from the dorsal aspect of the brain stem.

CLINICAL CORRELATES

Lesion of the trochlear nerve causes paralysis of the superior oblique muscle of the eye, which causes diplopia (double vision) and inability to look inferolaterally. Injuries are seen with severe head injuries or meningitis because of its long intracranial course.

E. Trigeminal Nerve (CN V) (Figures 9.3 to 9.4)

- Develops in association with the first branchial arch and supplies motor fibers (SVE) to the muscles of mastication, as well as the mylohyoid, anterior belly of the digastric muscle, and tensor tympani and tensor veli palatini.
- This is a major sensory nerve (general somatic afferent [GSA]) supplying fibers to the face, scalp, auricle, external auditory meatus, nose, paranasal sinuses, mouth (except the posterior one-third of the tongue), parts of the nasopharynx, auditory tube, and cranial dura mater.
- The ganglion (**semilunar or trigeminal ganglion**) consists of cell bodies of sensory fibers that distribute along three nerve paths designated V1, V2, and V3 (see Ophthalmic Division (V1), Maxillary Division (V2), and Mandibular Division (V3)). The trigeminal ganglion occupies the

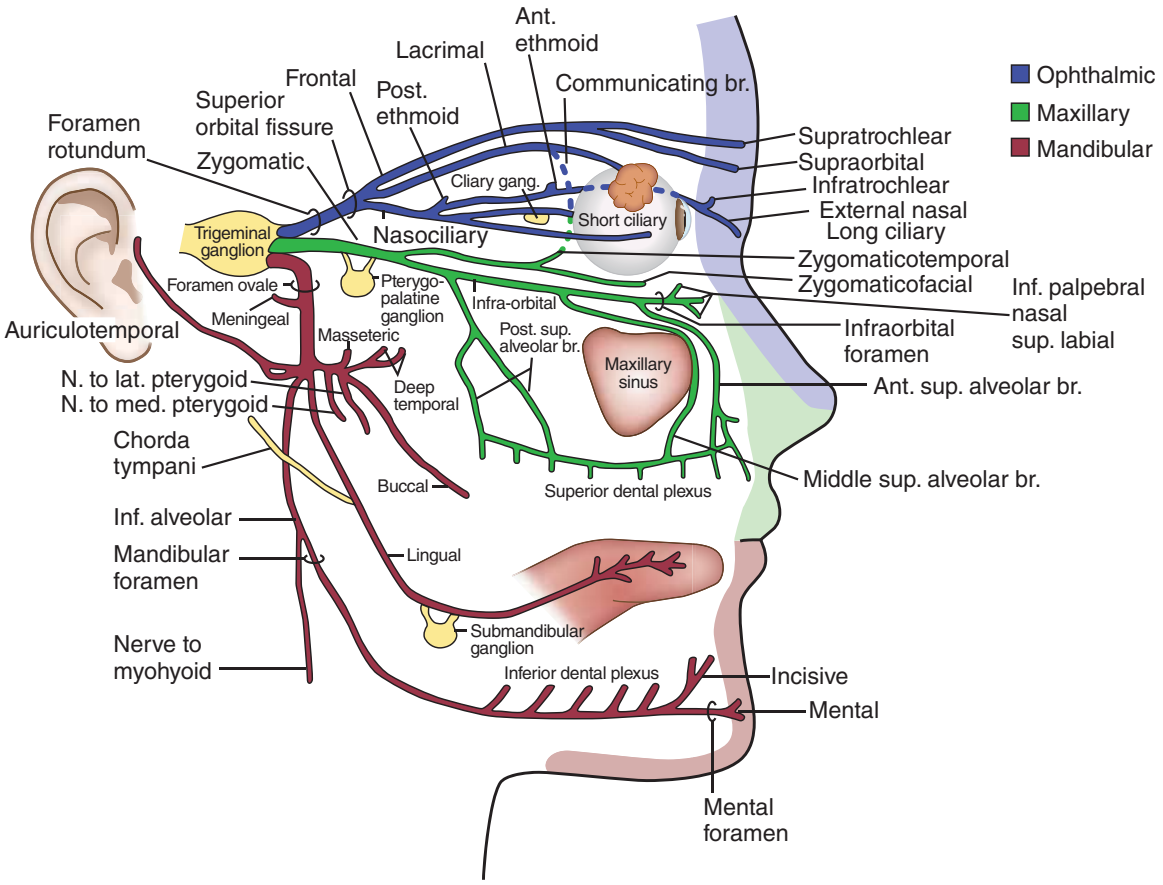

FIGURE 9.3. Branches of the trigeminal nerve.

trigeminal impression at the apex of the petrous portion of the temporal bone in the middle cranial fossa. The ganglion itself is housed in a pouch webbed with arachnoid between two layers of dura (**Meckel cave**).

1. **Ophthalmic Division (V1) (See Orbit: II. A, Chapter 8)**
   - Runs in the dura of the lateral wall of the cavernous sinus and enters the orbit through the **supraorbital fissure**.
   - Provides sensory innervation to the eyeball, tip of the nose, and skin of the face above the eye.
   - Mediates the **afferent limb of the corneal reflex** by way of the nasociliary branch, whereas the facial nerve mediates the efferent limb.
   - Major branches of the ophthalmic division (V1) include the following:
     1. **Lacrimal nerve** supplies sensation to the lacrimal gland, the conjunctiva, and the skin of the upper lateral eyelid.
     2. **Frontal nerve** divides into the supraorbital and supratrochlear nerve and supplies the scalp, forehead, frontal sinus, and upper central eyelid.
     3. **Nasociliary nerve** gives rise to a number of branches:
        - A communicating branch to the ciliary ganglion.
        - Short ciliary nerves, which carry postganglionic parasympathetic and sympathetic and afferent fibers.
        - Long ciliary nerves, which carry postganglionic sympathetic fibers to the dilator pupillae and afferent fibers from the iris and cornea.
        - Posterior ethmoidal nerve, which supplies the sphenoidal and posterior ethmoidal sinuses.
        - Anterior ethmoidal nerve, which supplies the anterior ethmoidal air cells and divides into the internal and external nasal branches.
        - Infratrochlear nerve, which innervates the eyelids, conjunctiva, skin of the nose, and lacrimal sac.
     4. **Meningeal branch** supplies dura in the anterior cranial fossa.

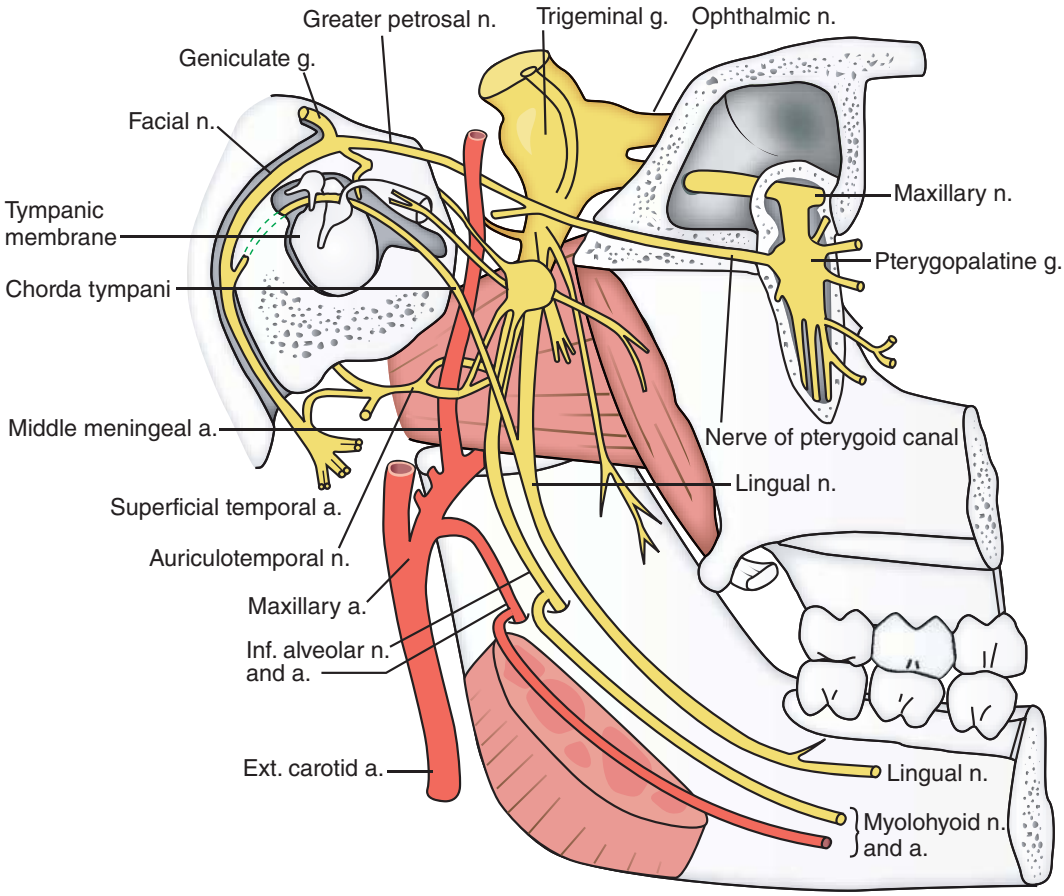

FIGURE 9.4. Trigeminal and facial nerves, and otic and pterygopalatine ganglia viewed from the medial side.

2. **Maxillary Division (V2) (See Pterygopalatine Fossa: II. A, Chapter 8)**
   - Passes through the lateral wall of the cavernous sinus of the middle cranial fossa and through the **foramen rotundum** to enter the pterygopalatine fossa (at the back of the orbit).
   - Sensory fibers (GSA) provide innervation to the face below the eyes and to the upper lip), palate, paranasal sinuses, and maxillary teeth.
   - The cell bodies for these sensory fibers are in the trigeminal ganglion in the middle cranial fossa.
   - These sensory fibers mediate the **afferent limb of the sneeze reflex** (irritation of the nasal mucosa), and the vagus nerve mediates the efferent limb.
   - Major branches of this complex nerve include the following:
     1. **Meningeal branch** innervates the dura mater of the middle cranial fossa.
     2. **Pterygopalatine (communicating) nerve** connects sensory fibers that pass through the pterygopalatine ganglion and join branches off the ganglion.
     3. **Posterior–superior alveolar nerve** leaves the pterygopalatine fossa to innervate the cheeks, gums, molar teeth, as well as the maxillary sinus.
     4. **Zygomatic nerve** courses through the zygomatic bone in the maxillary sinus and divides into the zygomaticofacial and zygomaticotemporal nerves. The latter carries postganglionic parasympathetic fibers destined for the lacrimal nerve to stimulate lacrimal secretion.
     5. **Infraorbital nerve** is the anterior continuation of the maxillary nerve and gives rise to the middle and anterior-superior alveolar nerves that supply the maxillary sinus, teeth, and gums. It then emerges through the infraorbital foramen and divides in the face into the inferior palpebral, lateral nasal, and superior labial branches.
     6. **Branches of the maxillary division that pass through the pterygopalatine ganglion** without synapsing include the following:
        - Orbitalbranches, whichsupplythe orbit and posterior ethmoidal and sphenoidal sinuses.

- Pharyngeal branch, which supplies the roof of the pharynx and sphenoidal sinus.
- Posterior–superior lateral nasal branches, which innervate the nasal septum, posterior ethmoidal air cells, and superior and middle conchae.
- Greater palatine nerve, which innervates the hard palate and the inner surface of the maxillary gingiva.
- Lesser palatine nerve, which innervates the soft palate and palatine tonsil and contains general sensory fibers and taste fibers (from the greater petrosal branch of the facial).
- Nasopalatine nerve, which supplies the nasal septum, the hard palate, incisors, the skin of the phyltrum,and the gums.

3. **Mandibular Division (V3) (See Temporal and Infratemporal Fossae: III. A, Chapter 8)**
   - Passes from the middle cranial fossa through the **foramen ovale** to supply motor fibers (SVE) to the muscles from the first branchial arch, which include the tensor veli palatini, tensor tympani, anterior belly of the digastric, and mylohyoid muscle as well as the muscles of mastication (temporalis, masseter, and lateral and medial pterygoid).
   - Provides sensory innervation (GSA) to the lower part of the face, including the lower lip, anterior ear and chin as well as the mandibular teeth, and anterior two-thirds of the tongue.
   - Mediates the afferent and **efferent limbs of the jaw jerk reflex**.
   - The following are branches of V3:
     1. **Meningeal branch** supplies the dura in the middle cranial fossa.
     2. **Muscular branches** include the masseteric, deep temporal, medial pterygoid, and lateral pterygoid branches.
     3. **Buccal nerve** innervates skin on the buccinator and the mucous membrane of the cheek and gums.
     4. **Lingual nerve** supplies general sensation to the anterior two-thirds of the tongue. The chorda tympani joins the lingual nerve in the infratemporal fossa. The functions of chorda tympani are covered under the CN VII section.
     5. **Inferior alveolar nerve** gives rise to several important branches:
        - Mylohyoid nerve, which innervates the mylohyoid and anterior belly of the digastric muscles.
        - Inferior dental branch, which innervates the lower teeth.
        - Mental nerve, which innervates the skin over the chin.
        - Incisive branch, which innervates the mandibular canine and incisors.

CLINICAL CORRELATES

Lesion of the trigeminal nerve causes sensory loss on the face and weakness of the muscles of mastication that manifests as a deviation of the mandible toward the side of the lesion. Lesion of the **lingual nerve** near the neck of the third molar causes loss of general sensation and taste to the anterior two-thirds of the tongue as well as salivary secretion from submandibular and sublingual glands (due to loss of preganglionic parasympathetic fibers from the chorda tympani branch of CN VII). Lesion of the **ophthalmic division** cannot mediate the afferent limb of the corneal reflex by way of the nasociliary branch (the facial nerve mediates the efferent limb). Lesion of the **maxillary division** cannot mediate the afferent limb of the sneeze reflex (vagus nerve mediates the efferent limb). Lesion of the **mandibular division** would be associated with loss of both the afferent and efferent limbs of the jaw jerk reflex.

Trigeminal neuralgia (tic douloureux) is marked by **paroxysmal pain** along the course of the trigeminal nerve, especially radiating to the maxillary or mandibular area. The common causes of this disorder are aberrant blood vessels, aneurysms, chronic meningeal inflammation, brain tumors compressing on the trigeminal nerve at the base of the brain, and other lesions such as multiple sclerosis. If medical treatments are not effective, the neuralgia may be alleviated by sectioning the sensory root of the trigeminal nerve in the trigeminal (Meckel) cave in the middle cranial fossa.

F. Abducens Nerve (CN VI) (Figure 9.2)

- Leaves the brain at the pontomedullary junction and then pierces the dura on the dorsum sellae of the sphenoid bone.
- Passes through the cavernous sinus and enters the orbit through the supraorbital fissure to supply motor fibers (GSE) to the lateral rectus.

CLINICAL CORRELATES

Lesion of the abducens nerve causes weakness/paralysis of the lateral gaze due to loss of the rectus muscle of the eye. The patient will present with a **medial deviation** of the affected eye (**internal strabismus**) or diplopia on lateral. It may result from a sepsis or thrombosis in the cavernous sinus. If the opposite side of the body is affected, there is a brain stem tumor or midline pontine stroke.

G. Facial Nerve (CN VII) (Figures 9.4, 9.5 and 9.7)

- Leaves the pons at the pontocerebellar angle as a large root, which carries motor fibers (SVE) to innervate the muscles of facial expression, and a smaller root, termed the nervus intermedius, which contains taste fibers (SVA) from the anterior two-thirds of the tongue. In addition, it contains preganglionic parasympathetic fibers (GVE) for the lacrimal, submandibular, sublingual, nasal, and palatine glands and visceral afferent fibers from the palate and nasal mucosa. A small number of fibers carry general sensory fibers from the external acoustic meatus and the auricle.
- Is the nerve of the second branchial arch.
- Enters the **internal acoustic meatus**, the **facial canal** in the temporal bone, and the main trunk emerges from the **stylomastoid foramen** to form terminal branches.
- All sensory cell bodies for the facial nerve reside in the **geniculate ganglion**, which lies at the external bend or genu (Latin for "knee") within the petrous portion of the temporal bone.
- Mediates the closure of the orbicularis oculi, which is the efferent limb of the **corneal (blink) reflex**.
- Lesion produces Bell's palsy (facial paralysis), which will affect all muscles of facial expression on the side of the lesion.
- Gives rise to the following branches:

1. **Greater Petrosal Nerve**
   - Contains preganglionic parasympathetic fibers destined for the pterygopalatine ganglion and joins the deep **petrosal nerve** (containing postganglionic sympathetic fibers) to form the **nerve of the pterygoid canal** (Vidian nerve).
   - Carries taste sensation (from anterior two-thirds of tongue) and visceral afferent fibers from the palate.
2. **Communicating Branch**
   - Joins the lesser petrosal nerve.
3. **Stapedial Nerve**
   - Supplies motor fibers to the stapedius, which helps attenuate loud sound.
4. **Chorda Tympani**
   - Arises in the descending part of the facial canal and crosses the tympanic membrane, passing between the handle of the malleus and the long process of the incus.
   - Exits the skull through the **petrotympanic fissure** and joins the lingual nerve in the infratemporal fossa.
   - Contains preganglionic parasympathetic fibers (GVE) that synapse on postganglionic cell bodies in the **submandibular ganglion**. Their postganglionic fibers innervate the submandibular, sublingual, and lingual glands.
   - Also contains taste fibers (SVA) from the anterior two-thirds of the tongue (ectodermal tongue), with cell bodies located in the geniculate ganglion.
   - May communicate with the otic ganglion below the base of the skull.
5. **Muscular Branches**
   - Supply motor fibers (SVE) to the stylohyoid and the posterior belly of the digastric muscle.
6. **Fine Communicating Branch**
   - Joins the auricular branch of the vagus nerve and the glossopharyngeal nerve to supply GSA fibers to the external ear.

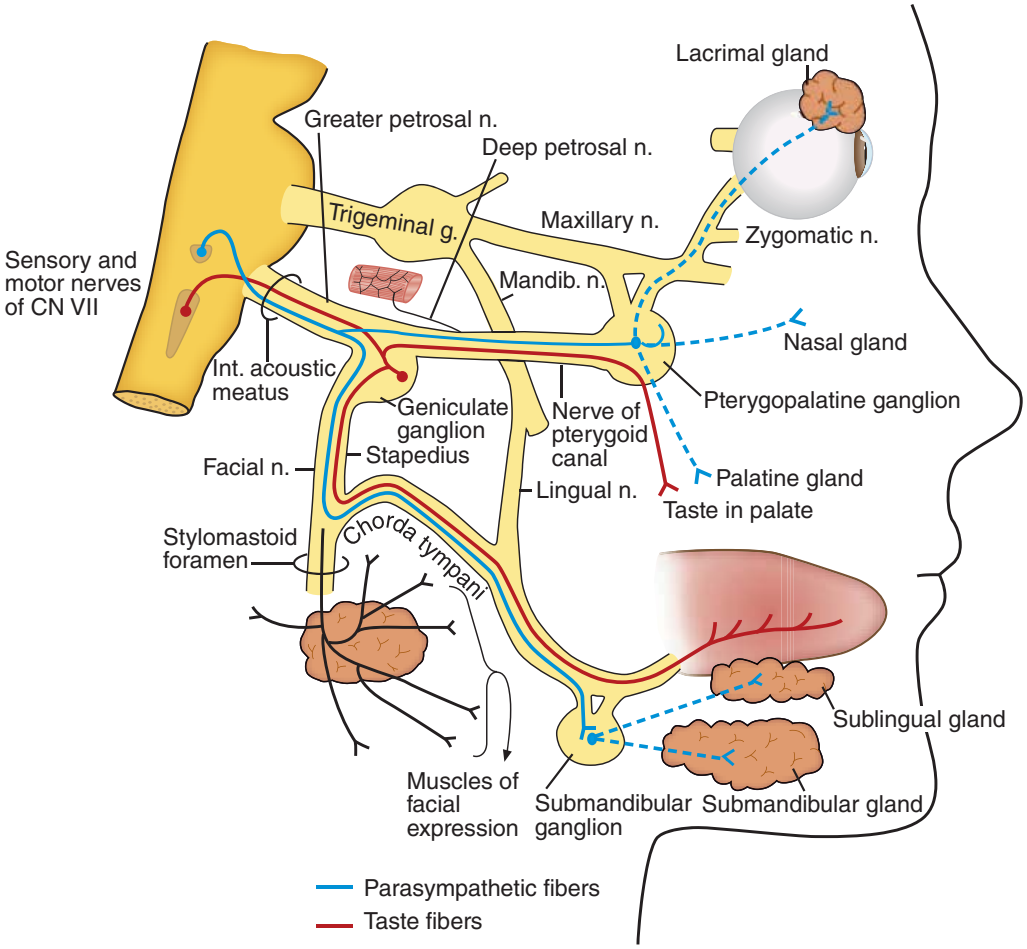

FIGURE 9.5. Distribution of the facial nerve.

7. **Posterior Auricular Nerve**
   - Runs behind the auricle with the posterior auricular artery.
   - Supplies SVE fibers to the muscles of the auricle and the occipitalis muscle.
8. **Terminal Branches**
   - Arise in the parotid gland and radiate onto the face as the temporal, zygomatic, buccal, marginal mandibular, and cervical branches.
   - Supply motor fibers (SVE) to the muscles of facial expression.

CLINICAL CORRELATES

Lesion of the facial nerve causes **Bell's palsy**, which is marked by characteristic **distortion of the face** such as no wrinkles on the forehead, drooping of the eyebrow, inability to close or blink the eye, sagging corner of the mouth, and inability to smile, whistle, or blow. The palsy also causes loss of taste in the anterior two-thirds of the tongue, decreased salivary secretion and lacrimation, painful sensitivity to sounds, and deviation of the lower jaw. Facial paralysis may be caused by a lesion of the facial nerve, a stroke, or a brain tumor. A **central lesion** of the facial nerve results in paralysis of muscles in the lower face on the contralateral (opposite) side; consequently, forehead wrinkle is not impaired. Therefore, the patient with **peripheral facial palsy** shows **no wrinkles** on the affected side, but the patient with a **stroke** or a **brain tumor** shows **wrinkles on both sides**. The definite cause of Bell palsy is unknown, but it may be caused by herpes simplex (viral) infection. Its treatment includes a course of steroid treatment – 60 to 80 mg of prednisone (anti-inflammatory drug) daily during the first 5 days, followed by tapering doses over the next 5 days, which may help reduce paralysis and expedite recovery by reducing inflammation and swelling and relieving pressure on the facial nerve for some patients. Treatment also includes antiviral drugs, such as acyclovir alone or in combination with prednisone. The patient is advised to protect the eyes from drying out with artificial tears and eye patches. Recovery is likely to take a few weeks to months.

H. Vestibulocochlear (Acoustic or Auditory) Nerve (CN VIII) (Figure 9.1)

- Leaves the pontocerebellar angle laterally and enters the internal acoustic meatus (with the facial nerve) and remains within the temporal bone to supply sensory fibers to the sensory cells of the inner ear.
- The **cochlear portion** (for hearing) derives from bipolar neurons in the spiral (cochlear) ganglion that innervate the hair cells of the cochlea (organ of Corti).
- The **vestibular portion** (for equilibrium) arises from bipolar neurons in the vestibular ganglion that innervate sensory cells of the ampullae of the semicircular ducts as well as the utricle and saccule.

CLINICAL CORRELATES

Lesion of the vestibulocochlear nerve causes loss of hearing or vestibular sense. The most common loss of hearing is the loss of hair cells of the cochlea (organ of Corti) that occurs for high tones with advanced age (**presbycusis**). Disruptions of the ampullae of the semicircular ducts, and the utricle and saccule would result in **vertigo** (dizziness, loss of **balance**). Other problems with the labyrinth may cause **tinnitus** (ringing or buzzing in ears).

I. Glossopharyngeal Nerve (CN IX) (Figures 9.1 and 9.7)

- Is the nerve of the third branchial arch and contains SVE, SVA (taste), GVE, general visceral afferent (GVA), and GSA fibers.
- Leaves the postolivary sulcus of the lateral medulla to pass through the **jugular foramen** and gives rise to the following branches:

1. **Tympanic Nerve**
   - Forms the **tympanic plexus** on the medial wall of the middle ear with sympathetic fibers from the internal carotid plexus (caroticotympanic nerves) and a branch from the geniculate ganglion of the facial nerve.
   - Conveys visceral sensory fibers to the tympanic cavity, the mastoid antrum and air cells, and the auditory tube.
   - Continues beyond the plexus as the **lesser petrosal nerve** in the floor of the middle cranial fossa and leaves through the foramen ovale to bring preganglionic parasympathetic fibers to the otic ganglion. Postganglionic parasympathetic fibers leave the otic ganglion to innervate the parotid gland.
2. **Communicating Branch**
   - Joins the auricular branch of the vagus nerve and provides general sensation and pain fibers to the ear.
3. **Pharyngeal Branch**
   - Supplies visceral sensory fibers to the posterior tongue and pharyngeal wall, including the tonsillar bed. It joins with the pharyngeal branch of the vagus nerve and branches from the sympathetic trunk to form the pharyngeal plexus on the middle constrictor muscle.
   - Sensory fibers mediate the afferent limb of the gag (pharyngeal) reflex. The vagus nerve mediates the efferent limb.
4. **Carotid Sinus Branch**
   - Supplies baroreceptive and chomoreceptive fibers (GVA) to the carotid sinus and the carotid body (respectively).
   - Mediates the afferent limbs of the carotid sinus and body reflexes that can cause a drop in heart rate and blood pressure with carotid massage. The vagus nerve mediates the efferent limb.
5. **Tonsillar Branches**
   - Supplies sensory fibers to the palatine tonsil and the soft palate.
6. **Motor Branch**
   - Supplies motor fibers (SVE) to the stylopharyngeus.
7. **Lingual Branch**
   - Supplies taste and visceral afferent fibers to the posterior one-third of the tongue and the vallate papillae (endodermal tongue behind the terminal sulcus).

CLINICAL CORRELATES

Lesion of the glossopharyngeal nerve causes loss of motor fibers to the **stylopharyngeus** muscle; **loss of taste on the posterior one-third** of the tongue and vallate papillae; **loss of parasympathetic supply to the parotid** via fibers to the otic ganglion; loss of visceral afferents fibers to the pharynx, the carotid body and sinus, posterior one-third of the tongue, tympanic cavity, the mastoid antrum and air cells, and the auditory tube; and loss of general sensory fibers to the external ear. Lesions result in loss of the **afferent limb of the gag** (pharyngeal) reflex. Pharyngitis can lead to glossopharyngeal neuralgia, which manifests as sore throat and horrible ear pain without corresponding ear infection.

J. Vagus Nerve (CN X) (Figures 9.1, 9.3 and 9.7)

- Is the nerve of the fourth and sixth branchial arches.
- Passes out of the postolivary sulcus to exit the posterior cranial fossa through the jugular foramen.
- Provides motor innervation (SVE) to all muscles of the larynx, pharynx (except the stylopharyngeus), and palate (except the tensor veli palatini).
- Also provides parasympathetic preganglionic innervation (GVE) to smooth muscles and glands of the pharynx, esophagus, and gastrointestinal track (from the stomach to the transverse colon) as well as for the cardiac muscle of the heart; and visceral afferent fibers (GVA) from all mucous membranes in the lower pharynx, larynx, trachea, bronchus, esophagus, and thoracic and abdominal visceral organs (except for the descending colon, sigmoid colon, rectum, and other pelvic organs).
- Mediates the afferent and efferent limbs of the **cough reflex** (caused by irritation of the bronchial mucosa) and the efferent limbs of the **gag (pharyngeal) reflex** and **sneeze reflex**.
- During phonation, a lesion is revealed by the loss of palate elevation and the uvula deviates toward the intact side, away from the side of the lesion.
- Gives rise to the following branches:

1. Meningeal Branch

- Arises from the superior ganglion and supplies the dura mater of the posterior cranial fossa.

2. Auricular Branch

- Is joined by a branch from the glossopharyngeal nerve and the facial nerve and supplies general sensory fibers to the external acoustic meatus.

3. Pharyngeal Branch

- Supplies motor fibers to all the skeletal muscles of the pharynx, except the stylopharyngeus, by way of the pharyngeal plexus and all muscles of the palate except the tensor veli palatini.
- Gives rise to the **nerve to the carotid body**, which supplies visceral fibers to the carotid body and the carotid sinus.

4. Superior, Middle, and Inferior Cardiac Branches

- Carry parasympathetic supply toward, and visceral afferent fibers back from, the cardiac plexuses.

5. Superior Laryngeal Nerve

- Divides into internal and external branches:

a. Internal Laryngeal Nerve

- Provides general sensory fibers to the larynx above the vocal cord, lower pharynx, and epiglottis.
- Supplies taste fibers to the taste buds on the root of the tongue near and on the epiglottis.

b. External Laryngeal Nerve

- Supplies motor fibers to the cricothyroid and inferior pharyngeal constrictor muscles.

6. Recurrent Laryngeal Nerve

- Hooks around the subclavian artery on the right and around the arch of the aorta lateral to the ligamentum arteriosum on the left.
- Ascends in the groove between the trachea and the esophagus.

- Provides general sensory fibers to the larynx below the vocal cord and motor fibers to all muscles of the larynx except the cricothyroid muscle.
- Becomes the **inferior laryngeal nerve** at the lower border of the cricoid cartilage.

CLINICAL CORRELATES

Lesion of the vagus nerve causes **dysphagia** (difficulty in swallowing) resulting from lesion of pharyngeal branches; numbness of the upper part of the larynx and paralysis of cricothyroid muscle resulting from lesion of the superior laryngeal nerve; and hoarseness, **dysphonia** (difficulty in speaking), **aphonia** (loss of voice), and numbness of the lower part of the larynx resulting from lesion of the recurrent laryngeal nerve. Lesion results in **deviation of the uvula toward the uninjured side** on phonation. Lesion cannot mediate the afferent and efferent limbs of the **cough reflex** and the efferent limbs of the **gag (pharyngeal) reflex** and **sneeze reflex**. In addition, lesion causes loss of motor fibers to muscles of the larynx, pharynx (except the stylopharyngeus), and palate (except the tensor veli palatini); **loss of taste on the epiglottis**; and loss of parasympathetic supply to the thorax and abdomen as well as some visceral afferents.

K. Accessory Nerve (CN XI) (Figure 9.1)

- The spinal root leaves the upper cervical spinal cord laterally to pass into the posterior cranial fossa through the foramen magnum before it passes out of the skull through the jugular foramen.
- Provides motor fibers to the sternocleidomastoid and trapezius muscles.
- The cranial portion contains motor fibers that exit the medulla and pass through the jugular foramen where they join the vagus nerve as the recurrent laryngeal nerve to supply muscles of the pharynx and larynx.

CLINICAL CORRELATES

Lesion of the spinal accessory nerve causes loss of motor fibers to the sternocleidomastoid and trapezius muscles. The arm cannot be abducted beyond the horizontal position as a result of an inability to rotate the scapula. Lesion also causes **torticollis** because of paralysis of the sternocleidomastoid and shoulder drop from paralysis of the trapezius.

L. Hypoglossal Nerve (CN XII) (Figures 9.1 and 9.3)

- Passes out of the medulla ventrally in the preolivary sulcus and passes through the **hypoglossal canal**.
- Loops around the occipital artery and the carotid bifurcation to pass between the carotids and internal jugular vessels. It runs deep to the digastric posterior belly and stylohyoid muscles to enter the submandibular triangle.
- It enters the mouth by passing above the greater horn of the hyoid bone between the middle pharyngeal constrictor and the mylohyoid muscle.
- Supplies motor fibers to all of the intrinsic and extrinsic muscles of the tongue except the palatoglossus (which is supplied by the vagus nerve).
- Carries sensory fibers from C1 to supply the cranial dura mater through the meningeal branch, but the fibers are not components of the hypoglossal nerve.
- Not strictly part of the hypoglossal nerve, it also carries motor fibers from C1 to supply the upper root of the ansa cervicalis and the nerve to both the thyrohyoid and geniohyoid muscles.
- Lesion causes deviation of the tongue toward the injured side on protrusion.

CLINICAL CORRELATES

Lesion of the hypoglossal nerve causes loss of motor fibers to all of the intrinsic and extrinsic muscles of the tongue except the palatoglossus, which is supplied by the vagus nerve. Lesion causes **deviation of the tongue toward the injured side** on protrusion. Hence, a mnemonic to remember the deviation side is "*you lick your wounds*."

M. Structures Derived from Pharyngeal (Branchial) Arch

Arch	Nerve	Muscles	Skeletal Structures
First (mandibular)	CN V	Muscles of mastication, mylohyoid, digastric anterior belly, tensor tympani	Meckel cartiage: malleus, incus, sphenomandibular ligament
Second (hyoid)	CN VII	Muscles of facial expression, mylohyoid, digastric posterior belly, stylohyoid, stapedius	Stapes, stylohyoid process, lesser horn and upper body of hyoid bone, stylohyoid ligament
Third	CN IX	Stylopharyngeus	Greater horn and lower body of hyoid bone
Fourth	CN X (superior laryngeal nerve)	Muscles of pharynx except tensor veli palatini, muscles of pharynx except stylopharyngeus, crycothyroid	Thyroid and cricoid cartilages
Sixth	CN X (recurrent laryngeal nerve)	Intrinsic muscles of larynx except crycothyroid	Arytenoid, corniculate, and cuneiform cartilages

N. Cranial Nerve Examination

CN I	Smell tested by placing stimuli under one nostril at a time and occluding the other nostril.
CN II	**Visual acuity** is tested by asking to read progressively smaller prints on the near card or Snellen charts (tested with Snellen charts); **color vision** is tested with Ishihara color plate; **visual fields** by having the patient count presented fingers in each of the four quadrants of the tested eye, with the opposite covered; and afferent limb of **pupillary light reflex** by shinning a penlight into one eye and check the pupils on both sides for direct or consensual response.
CNs III, IV, and VI	Extra and intraocular muscles are tested by examining smoothness of eye movements, checking for ptosis, presence of pupillary light reflex, and the accommodation reflex. The accommodation reflex includes eye convergence and pupil constriction. The efferent component of the pupillary reflex is via CN III.
CN V	Sensory is tested by lightly touching the forehead (V1); by touching the cheeks (V2); and by touching the chin; motor (V3) is tested by clenching teeth together, opening mouth, and protruding jaw; corneal reflex) by lightly touching the cornea with the cotton wool (sensation V1) and observing the eye closing (motor with CN VII).
CN VII	Motor by checking wrinkles in forehead, raise eyebrows, smile, puff out cheeks and conducting corneal reflex (with CN V), and testing for taste.
CN VIII	Grossly tested with whisper test and then localization of hearing loss tested by conducting Rinne and Weber tests using a tuning fork; vestibular functions are tested by observing vertigo (Hallpike test) or disturbance of equilibrium (Romberg test).
CN IX	Tested with the gag reflex or by touching the pharynx (sensory IX) with a tongue depressor and the palate elevates (motor IX).
CN X	Tested by observing the symmetrical elevation of the uvula as the patient says "aah."
CN XI	Shrug shoulder and turn head from side to side.
CN XII	Examine symmetry of the tongue or any deviation when protruding the tongue.

II. AUTONOMIC NERVES OF THE HEAD (Figures 9.5 to 9.6; Table 9.4)

A. Sympathetics of the Head and Neck

- The **cervical portion of the sympathetic trunk** contains three sympathetic ganglia that are interconnected: the **superior**, **middle**, and **inferior cervical ganglia**. The **superior cervical ganglion** is at the level of the C1 and C2 vertebrae. The **middle cervical ganglion** lies at the level of the cricoid cartilage. The **inferior cervical ganglion** is usually fused with the first thoracic ganglion to form the **stellate ganglion**. Each cervical ganglion receives preganglionic nerve fibers from the upper thoracic spinal nerves. Postganglionic neurons send fibers to the head and neck visceral organs as well as cardiac nerves to the thorax.
- **Inferior cervical ganglion** provides postganglionic fibers through the **inferior cardiac nerve** to the **cardiopulmonary plexus** (heart/lungs) and other fibers to the inferior segments of the brachial plexus. Some fibers interconnect the inferior cervical ganglion and the first thoracic ganglion by coursing around the subclavian artery (**ansa subclavius**).

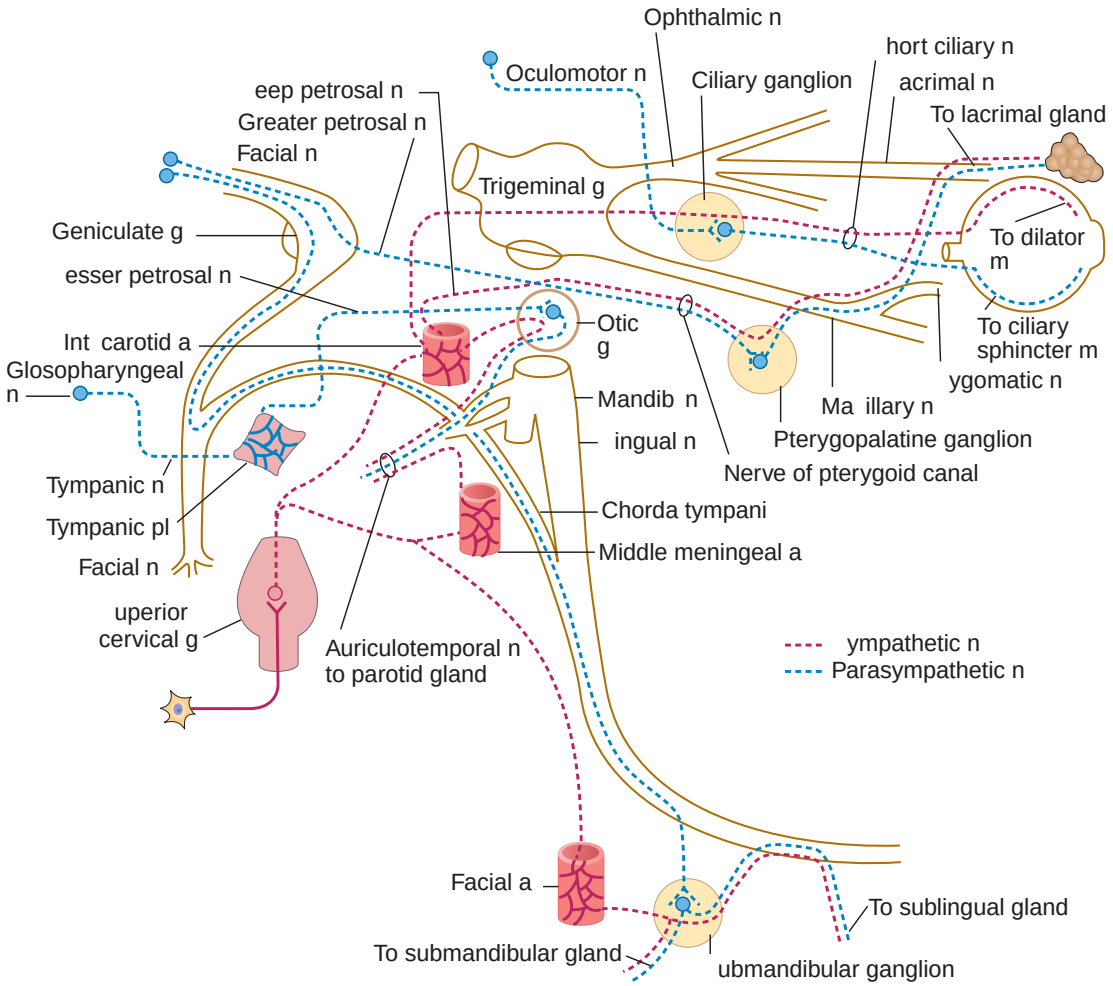

FIGURE 9.6. Autonomics of the head and neck including four parasympathetic ganglia. Note that (1) parasympathetic preganglionic nerve fibers run in the oculomotor nerve, synapse in the ciliary ganglion, and postganglionc fibers run in the short ciliary nerve to supply the ciliary and sphincter muscles; (2) parasympathetic preganglionic nerve fibers run through the facial nerve, greater petrosal nerve, nerve of pteryfoid canal, synapse in the pterygopalatine ganglion, and post-ganglionic fibers run in the maxillary, zygomatic, zygomaticotemporal, and lacrimal nerves to supply the lacrimal gland; (3) another parasympathetic preganglionic nerve fibers run in the facial nerve, chorda tympani, lingual nerve, synapse in the submandibular ganglion, and postganglionic fibers supply submandibular, sublingual, and lingual glands; (4) parasym-pathetic preganglionic nerve fibers run in the glossopharyngeal nerve, tympanic plexus, lesser petrosal nerve, synapse in the otic ganglion, and postganglionic fibers run in the auriculotemporal nerve to supply the parotid gland. For sympathetic nerve, preganglionic sympathetic nerve fibers arise from the upper thoracic sympathetic chain ganglia, synapse in the superior cervical ganglion, and postganglionic fibers run along the blood vessel, accompanying parasympathetic fibers to supply blood vessels, sweat glands, and other tissues.

table 9.4 Parasympathetic Ganglia and Associated Autonomic Nerves

Ganglion	Location	Parasympathetic Fibers	Sympathetic Fibers	Chief Distribution
Ciliary	Lateral to optic nerve	Oculomotor nerve and its inferior division	Internal carotid plexus	Ciliary muscle and sphincter pupillae (parasympathetic); dilator pupillae and tarsal muscles (sympathetic)
Pterygopalatine	In pterygopalatine fossa	Facial nerve, greater petrosal nerve, and nerve of pterygoid canal	Internal carotid plexus	Lacrimal gland and glands in palate and nose
Submandibular	On hyoglossus	Facial nerve, chorda tympani, and lingual nerve	Plexus on facial artery	Submandibular and sublingual glands
Otic	Below foramen ovale	Glossopharyngeal nerve, its tympanic branch, and lesser petrosal nerve	Plexus on middle meningeal artery	Parotid gland

- **Middle cervical ganglion** provides postganglionic fibers through the **middle cardiac nerve** to the **cardiopulmonary plexus** (heart/lungs) and other fibers that supply the upper segments of the brachial plexus and the lower segments of the cervical plexus.
- **Superior cervical ganglion** provides postganglionic fibers through the **superior cardiac nerve** to the **cardiopulmonary plexus** (heart/lungs) and other fibers supply the upper segments of the cervical plexus. In addition, sympathetic postganglionic fibers for the head travel through two routes to all destinations in the head: through the **carotid plexus** and the **deep petrosal nerve**.
  1. **Carotid Plexus**
     - These are postganglionic fibers that arise from neurons chiefly located in the superior cervical ganglion, and they distribute on the surface of either the internal or external carotid arteries. Thus, there is an internal carotid plexus and an external carotid plexus.
  2. **Deep Petrosal Nerve**
     - Arises from the plexus on the internal carotid plexus.
     - Contains **postganglionic sympathetic** fibers with cell bodies located in the superior cervical ganglion.
     - These fibers ascend through foramen lacerum to join the greater petrosal nerve and become the nerve of the pterygoid canal.
     - These sympathetic fibers pass through the pterygopalatine ganglion without synapsing, and then join the postganglionic parasympathetic fibers in supplying the lacrimal gland, the nasal glands, and glands of the palate.

B. Parasympathetics of the Head

- Four **cranial nerves** contain parasympathetic preganglionic nerve fibers. The head contains **four parasympathetic ganglia**. The first three cranial nerves provide the parasympathetic supply for the entire head, while the vagus is involved mostly with the pharynx, thorax, and abdomen. The trigeminal nerve does not have parasympathetic fibers as it leaves the middle cranial fossa. However, the distal branches of each division of the trigeminal acts like a scaffold to carry autonomic supply throughout the head.
- In the eye, smooth muscle of the ciliary apparatus and the sphincter pupillae are supplied by the **oculomotor nerve.** The **parasympathetic preganglinic nerve** fibers travel from neurons located in the Edinger–Westphal nucleus of the midbrain (mesencephalon). They travel along the inferior division of the oculomotor nerve and enter the **ciliary ganglion** where they synapse. Postganglionic fibers distribute with the short ciliary nerve branches of the trigeminal nerve and supply the **ciliary muscle** and **spincter pupillae**.
- The major parasympathetic nerve of the head is the **facial nerve** and it supplies all secretory elements from the lacrimal glands to the hyoid bone with only one exception (the parotid gland). The **facial nerve** carries parasympathetic preganglionic fibers along two different paths. The first is associated with the maxillary prominence of the first branchial arch. The greater petrosal nerve gives rise to the parasympathetic portion of the nerve of the pterygoid canal (Vidian nerve). These fibers enter the **pterygopalatine ganglion** where they synapse. Postganglionic nerve fibers distribute through the branches of CN V2 to the **lacrimal gland** as well as to the nasal and palatine glands. The second pathway supplies structures associated with the mandibular prominence of the first branchial arch. These parasympathetic preganglionic nerve fibers branch from the facial nerve as the chorda tympani nerve. The chorda tympani joins the lingual nerve before the fibers synapse in the **submandibular ganglion**. Postganglionic nerve fibers supply the submandibular, sublingual, and lingual glands by traveling with sensory fibers of the lingual nerve.
- The **glossopharyngeal nerve** carries parasympathetic preganglionic nerve fibers destined to supply the otic ganglion and then the parotid gland. The preganglionic fibers run in the tympanic nerve, courses through the tympanic plexus and into the middle cranial fossa as the lesser petrosal nerve. The lesser petrosal nerve leaves the skull and preganglionic fibers synapse in the **otic ganglion**. Postganglionic nerve fibers join the auriculotemporal nerve and supply the **parotid gland** for salivary secretion.
- The **vagus nerve** conveys parasympathetic preganglionic nerve fibers that enter the **terminal ganglia** near or in the organs where they synapse. Postganglionic nerve fibers supply cardiac muscle, **smooth muscle**, and **glands** in the pharynx, larynx, trachea, and in thoracic and abdominal viscera.

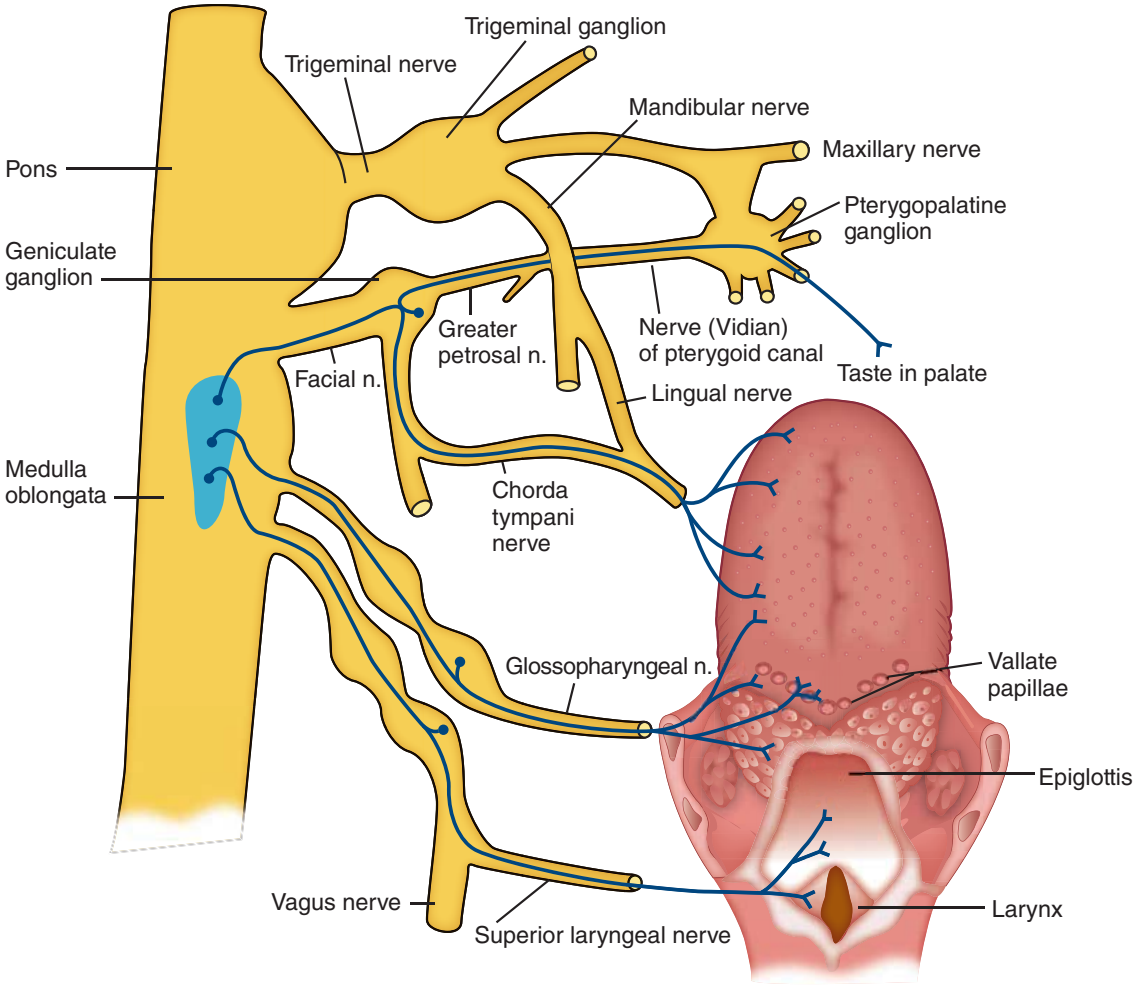

FIGURE 9.7. Cranial nerves that carry sensory fibers for taste (CN VII, IX, and X).

- The **trigeminal nerve** carries **no parasympathetic preganglionic nerve fibers**, but its branches provide pathways for parasympathetic nerve fibers to reach the target organs: (1) postganglionic parasympathetic fibers from the ciliary ganglion run in the **short cilliary nerve** and supply the ciliary muscle and sphincter pupillae; (2) postganglionic parasympathetic fibers from the pterygopalatine ganglion run in the **maxillary, zygomatic, zygomaticotemporal, and lacrimal nerve**, and supply the lacrimal gland; (3) postganglionic parasympathetic fibers from the otic ganglion run in the **auriculotemporal nerve** and supply the parotid gland; and (4) the **lingual nerve** joined by the chorda tympani in the infratemporal fossa carries preganglionic parasympathetic fibers, which synapse in the submandibular ganglion, and postganglionic fibers supply the submandibular gland and then may rejoin the lingual nerve to supply the sublingual and lingual glands.

CLINICAL CORRELATES

Horner syndrome is caused by **lesion of cervical sympathetic nerves** and characterized by (a) **miosis** (constriction of the pupil); (b) **ptosis** (drooping of the upper eyelid); (c) **enophthalmos** (retraction of the eyeball); (d) **anhidrosis** (absence of sweating); and (e) **vasodilation** (increased blood flow in the face and neck [flushing]). **Crocodile tears syndrome** is spontaneous lacrimation during eating, caused by a lesion of the facial nerve proximal to the geniculate ganglion. It is due to misdirection of regenerating parasympathetic fibers, which formerly innervated the salivary (submandibular and sublingual) glands and now stimulate the lacrimal glands. **Frey syndrome** is seen after parotidectomy as uncontrolled sweating over the angle of the mandible during eating. This occurs due to misdirection of regenerating parasympathetic fibers from the otic ganglion that wrongly innervate sweat glands.

HIGH-YIELD TOPICS

Cranial Nerves

- **Olfactory** nerve (SVA, smell).
- **Optic** nerve (SSA, vision).
- **Oculomotor** nerve carries parasympathetic (GVE) nerve fibers that supply the ciliary muscle (accommodation) and sphincter pupillae (constriction of the pupil) and mediate the efferent limb of the pupillary light reflex. It supplies all of the extraocular eye muscles except for the superior oblique and lateral rectus muscles.
- **Trochlear nerve** (GSE, the superior oblique muscle of the eye).
- **Trigeminal** nerve (GSA, skin on face; SVE, muscles of mastication and tensor veli palatini, tensor tympani, mylohyoid, and digastric anterior belly muscles).
- **Abducens** nerve (GSE, the lateral rectus muscle of the eye).
- **Facial** nerve (SVE, muscles of facial expression; SVA, taste on anterior two-thirds of tongue and palate; GVE, parasympathetic nerve to submandibular ganglion and gland, and to pterygopalatine ganglion and lacrimal, nasal, and palatine glands; GVA, nasal and palate mucosae; GSA, external ear).
- **Vestibulocochlear** nerve (SSA, hearing and balance).
- **Glossopharyngeal** nerve (SVE, stylopharyngeus muscle; SVA, taste on posterior one-third of tongue and vallate papillae; GVE, parasympathetic nerve to otic ganglion [parotid gland]; GVA, posterior one-third of tongue; GSA, external ear).
- **Vagus** nerve (SVE, muscles of palate, pharynx, and larynx; SVA, taste on epiglottis; GVE, parasympathetic nerve to smooth muscles, glands, and cardiac muscle in the thorax and abdomen; GVA, mucous membrane of the pharynx, larynx, middle ear cavity, and thoracic and abdominal viscerae; GSA, external ear).
- **Accessory** nerve (SVE, GSE, or mixed) to the trapezius and sternocleidomastoid muscles.
- **Hypoglossal** nerve (GSE, muscles of tongue movement).

Nerves and Muscles of Pharyngeal (Branchial) Arch (See Table under I. M.)

- The nerve of the **first arch,** the **trigeminal nerve** (mandibular branch), innervates muscles of mastication and mylohyoid, digastric anterior belly, and tensor tympani muscles.
- The nerve of the **second arch,** the **facial nerve**, innervates muscles of facial expression and the digastric posterior belly, stylohyoid, and stapedius muscles.
- The nerve of the **third arch**, the **glossopharyngeal nerve**, innervates the stylopharyngeus muscle.
- The nerve of the **fourth arch**, the **vagus nerve (superior laryngeal branch)**, innervates the muscles of the soft palate (except tensor veli palatini), crycothyroid, and muscles of the pharynx (except stylopharyngeus).
- The nerve of the **sixth arch**, the **vagus (recurrent laryngeal nerve)**, innervates the intrinsic muscles of the larynx (except the cricothyroid).

Muscle Innervation and Nerve Lesion

- **Muscles of the eye movement** are innervated by the oculomotor, trochlear, and abducens nerves. Formula to remember innervation of extraocular eye muscles is SO4, LR6, AO3 (**S**uperior **O**blique – CN4; **L**ateral **R**ectus – CN6; **A**ll **O**ther eye movement muscles – CN3).
- **Short ciliary nerve** carries postganglionic parasympathetic nerve fibers to the sphincter pupillae and ciliary muscle and postganglionic sympathetic fibers to the dilator pupillae. The **long ciliary nerve** also carries postganglionic sympathetic fibers.
- **Diplopia (double vision)** is caused by paralysis of one or more extraocular muscles resulting from injury of the nerves supplying them.
- **Lesion of the auriculotemporal nerve** damages postganglionic parasympathetic secretomotor fibers to the parotid gland and postganglionic sympathetic fibers to the sweat glands. When nerve is severed, the fibers can regenerate along each other's pathways and innervate the wrong gland, resulting in **Frey syndrome**, which produces flushing and sweating instead of salivation in response to taste of food.

- **Innervation of the tongue: GSE motor** – by CN XII; **GSA sensory** – anterior two-thirds by CN V3 and posterior one-third by CN IX; **SVA taste** – anterior two-thirds by CN VII, posterior one-third by CN IX, and epiglottis by CN X.
- **Lesion of the chorda tympani** results in loss of salivary secretion from the submandibular and sublingual glands and loss of taste from the anterior two-thirds of the tongue.
- **Bell palsy** (facial paralysis) caused by a **lesion of the facial nerve** is marked by characteristic **distortions of the face**, such as no wrinkles on the forehead, drooping of the eyebrow, inability to close or blink the eye, sagging corner of the mouth, and inability to smile, whistle, or blow. The palsy also causes loss of taste in the anterior portion of the tongue, decreased salivation and lacrimation, deviation of the lower jaw, and hyperacusis.
- **Crocodile tears syndrome** is spontaneous lacrimation during eating, caused by a lesion of the facial nerve proximal to the geniculate ganglion. It is due to misdirection of regenerating parasympathetic fibers, which formerly innervated the salivary (submandibular and sublingual) glands, to the lacrimal glands.
- **Recurrent laryngeal nerve** innervates the laryngeal muscles, and it should be identified and preserved during thyroid surgery. Its lesion could be produced during thyroidectomy or cricothyrotomy or by aortic aneurysm and may cause respiratory obstruction, hoarseness, inability to speak, and loss of sensation below the vocal cord.
- **Innervation of the nasal cavity: SVA olfaction** – by CN I; **GVA sensory** – by CN VII; **GVE secretomotor** to glands – by CN VII (parasympathetic nerve).
- **Nerve of the pterygoid canal** (Vidian nerve) is formed by the union of the greater petrosal (preganglionc parasympathetic) and deep petrosal (postganglionic sympathetic) nerves, and also carries SVA taste fibers from the palate and GVA sensory fibers from the palate and nasal mucosae. Its **lesion** results in vasodilation; a lack of secretion of the lacrimal, nasal, and palatine glands; and a loss of general and taste sensation of the palate.

Reflex ARCS

- Optic nerve mediates the afferent limb of the **pupillary light reflex**, whereas parasympathetic fibers in the oculomotor nerve mediate the efferent limb.
- Ophthalmic nerve mediates the afferent limb of the **corneal (blink) reflex** by way of the nasociliary branch, whereas the facial nerve mediates the efferent limb.
- Maxillary nerve mediates the afferent limb of the **sneeze reflex** (irritation of the nasal mucosa), and the vagus nerve mediates the efferent limb.
- Mandibular nerve mediates the afferent and efferent limbs of the **jaw jerk reflex**.
- Facial nerve mediates the efferent limb of the **corneal reflex**.
- Glossopharyngeal nerve (pharyngeal branch) mediates the afferent limb of the **gag (pharyngeal) reflex**, and the vagus nerve mediates the efferent limb of it.
- Vagus nerve mediates the afferent and efferent limbs of the **cough reflex** (irritation of the bronchial mucosa), and the efferent limbs of the gag and sneeze reflexes.

Cranial Nerves Carrying Taste Sensation

- SVA fibers for taste sensation from anterior two-thirds of the tongue run in the chorda tympani of the **facial nerve**.
- SVA fibers for taste sensation from posterior one-third of the tongue run in the **glossopharyngeal nerve**.
- Taste sensation from the palate is supplied by the **facial nerve** through its greater petrosal branch, which sends fibers into the palatine nerves.
- Taste sensation from the epiglottis is carried by the internal laryngeal branch of the superior laryngeal nerve, which is a branch of the **vagus nerve**.

Cranial Nerves Innervate Skeletal Muscles of the Head and Neck

- Oculomotor nerve (CN III): innervates all of the muscles of eye movement except the superior oblique and lateral rectus muscles.
- Trochlear nerve (CN IV): innervates the superior oblique muscle.
- Trigeminal nerve, mandibular division (CN V3): innervates the muscles of mastication, digastric anterior belly, mylohyoid, tensor belly palatini, and tensor tympani muscles.

- Abducens nerve (CN VI): innervates the lateral rectus muscle.
- Facial nerve (CN VII): innervates the muscles of facial expression, stylohyoid, digastric posterior belly, and stapedius muscles.
- Glossopharyngeal nerve CN IX): innervates the stylopharyngeus muscle.
- Vagus nerve (CN X): innervates all of the palate muscles except the tensor belly palatine muscle, all of the pharyngeal muscles except the stylopharyngeus muscle, and all of the laryngeal muscles.
- Accessory nerve (CN XI): innervates the trapezius and sternocleidomastoid muscles.
- Hypoglossal nerve (XII): innervates all of the tongue muscles except the palatoglossus muscle.

Functions of Autonomic Nerves

	Sympathetic Nerve	Parasympathetic Nerve
Eyes	Dilates pupil	Constricts pupil; contracts ciliary muscle to thicken lens
Lacrimal gland	Reduces secretion	Promotes secretion
Nasal mucous gland	Reduces secretion	Promotes secretion
Salivary gland	Reduces secretion and more viscid	Increases secretion and watery
Sweat gland	Stimulates secretion	No effect
Blood vessels	Constricts	No effect

Review Test

Directions: Each of the numbered items or incomplete statements in this section is followed by answers or by completions of the statement. Select the **one**-lettered answer or completion that is **best** in each case.

1. A 27-year-old man came to his physician with drooping of the upper eyelid (ptosis), a dilated pupil, and a difficulty in focusing on close objects. Furthermore, he has an internal strabismus (medial deviation of the eye) and inability to look inferiorly when the eye is adducted. Which of the following is the most likely cause?

(A) Lesion in the medulla
(B) Tumor in the optic canal
(C) Thrombosis in the cavernous sinus
(D) Lesion of the olfactory nerve
(E) Fracture of the foramen spinosum

2. A 16-year-old boy presents with double vision. Further examination reveals that he has difficulty in turning his eye inferolaterally and trouble going downstairs. Which of the following nerves is most likely damaged?

(A) Oculomotor nerve
(B) Optic nerve
(C) Ophthalmic nerve
(D) Trochlear nerve
(E) Abducens nerve

3. A 31-year-old man with a penetrating injury to the posterior triangle of the neck is unable to shrug his shoulder and turn the head to the opposite side. Which of the following nerves is most likely damaged?

(A) Trigeminal nerve
(B) Facial nerve
(C) Glossopharyngeal nerve
(D) Accessory nerve
(E) Hypoglossal nerve

4. A 23-year-old woman suffers from a fracture of the jugular foramen by car accident. Which of the following nerves is/are most likely damaged?

(A) Cranial nerve V2
(B) Cranial nerve VI
(C) Cranial nerves VII and VIII
(D) Cranial nerves IX, X, and XI
(E) Cranial nerve XII

5. A 17-year-old boy is involved in a gang fight and receives a penetrating injury to the neck. Which of the following conditions is most likely exhibited by this misadventure?

(A) Internal strabismus
(B) Trouble going down the stairs
(C) Constricted pupil
(D) Inability close the eye
(E) Deviation of tongue toward lesion side

6. A 28-year-old woman comes to her family physician and complains of difficulty in swallowing. Further examination reveals that she has no taste sensation of the posterior one-third of her tongue and a lack of secretion of the parotid gland. Which of the following would most likely cause this condition?

(A) Fracture of the mandibular canal
(B) Section of the zygomatic nerve
(C) Glossopharyngeal nerve injury
(D) Tumor in the pituitary gland
(E) Lesion of the hypoglossal nerve

7. A 34-year-old man in a bar fight suffers a knife wound that severs the abducens nerve proximal to its entrance into the orbit. Which of the following conditions results from this injury?

(A) Ptosis of the upper eyelid
(B) Loss of the ability to dilate the pupil
(C) External strabismus (lateral deviation)
(D) Loss of visual accommodation
(E) Internal strabismus (medial deviation)

8. Following radical resection of a primary tongue tumor, a 72-year-old patient has lost general sensation on the anterior two-thirds of the tongue. This is probably due to injury to branches of which of the following nerves?

(A) Trigeminal nerve
(B) Facial nerve
(C) Glossopharyngeal nerve
(D) Vagus nerve
(E) Hypoglossal nerve

9. A 53-year-old woman is diagnosed as having a pituitary tumor. If the tumor is large enough, she could exhibit which of the following disorders?

(A) Blindness
(B) Bitemporal (heteronymous) hemianopia
(C) Right nasal hemianopia
(D) Left homonymous hemianopia
(E) Binasal hemianopia

10. A patient can move his eyeballs normally and see distant objects clearly but cannot focus on near objects. This condition may indicate damage to which of the following structures?

(A) Ciliary ganglion and oculomotor nerve
(B) Oculomotor nerve and long ciliary nerve
(C) Short ciliary nerves and ciliary ganglion
(D) Superior cervical ganglion and long ciliary nerve
(E) Oculomotor, trochlear, and abducens nerves

11. A 32-year-old woman has hoarseness in her voice, and her uvula is deviated to the left on phonation. Which of the following nerve is most likely damaged?

(A) Right trigeminal nerve
(B) Left trigeminal nerve
(C) Right vagus nerve
(D) Left vagus nerve
(E) Left glosopharyngeal nerve

12. Following a penetrated injury in the submandibular triangle, the tongue of a 45-year-old patient deviates to the left on protrusion. Which of the following nerves is injured?

(A) Right lingual nerve
(B) Left lingual nerve
(C) Right hypoglossal nerve
(D) Left hypoglossal nerve
(E) Left glossopharyngeal nerve

13. A 47-year-old man cannot move his eyeball laterally. Which of the following conditions would cause such a clinical sign?

(A) Tumor of the pituitary gland
(B) Occlusion of the posterior cerebral artery
(C) Infection in the maxillary sinus
(D) Infection in the cavernous sinus
(E) Tumor in the anterior cranial fossa

14. A young boy with a tooth abscess from a longstanding infection suffers damage of the lingual nerve as it enters the oral cavity. Which of the following structures contain cell bodies of injured nerve fibers?

(A) Geniculate and otic ganglia
(B) Trigeminal and submandibular ganglia
(C) Trigeminal and dorsal root ganglia
(D) Geniculate and trigeminal ganglia
(E) Geniculate and pterygopalatine ganglia

15. A knife wound has severed the oculomotor nerve in a 45-year-old man. Which of the following conditions will occur because of this injury?

(A) Constricted pupil
(B) Abduction of the eyeball
(C) Complete ptosis
(D) Impaired lacrimal secretion
(E) Paralysis of the ciliary muscle

16. A 20-year-old guard at the gate of the Royal King's palace blinks his eyes when a strong wind hits the cornea of his eye. The afferent fibers of the corneal reflex arc are carried by which of the following nerves?

(A) Optic nerve
(B) Lacrimal nerve
(C) Nasociliary nerve
(D) Zygomatic nerve
(E) Oculomotor nerve

17. A 71-year-old man suffers from a known benign tumor in the pterygoid canal. Which of the following nerve fibers could be injured by this condition?

(A) Postganglionic parasympathetic fibers
(B) Taste fibers from the epiglottis
(C) General somatic afferent (GSA) fibers
(D) Preganglionic sympathetic fibers
(E) General visceral afferent (GVA) fibers

18. A 22-year-old patient has dryness of the corneal surface of his eye because of a lack of tears. Which of the following nerves may be damaged?

(A) Proximal portion of the lacrimal nerve
(B) Zygomatic branch of the facial nerve
(C) Lesser petrosal nerve
(D) Greater petrosal nerve
(E) Deep petrosal nerve

19. A 31-year-old hockey player is hit in the head by a puck. His radiogram shows a fracture of the foramen rotundum. Which of the following nerves would be damaged by this event?

(A) Ophthalmic nerve
(B) Mandibular nerve
(C) Maxillary nerve
(D) Optic nerve
(E) Trochlear nerve

20. Muscles derived from the second (hyoid) pharyngeal arch are innervated by which of the following cranial nerves?

(A) Trigeminal nerve
(B) Facial nerve
(C) Glossopharyngeal nerve
(D) Vagus nerve
(E) Accessory nerve

Answers and Explanations

1. **The Answer is C.** Thrombosis in the cavernous sinus might damage all three CNs (III, IV, VI): lesion of CN III causes ptosis, a dilated pupil, and loss of accommodation; lesion of CN IV causes inability to look inferiorly when adducted; and lesion of CN VI causes the eyeball deviates medially (internal strabismus). Lesion in the medulla may damage CNs IX, X, and XII. Tumor in the optic canal injures the optic nerve and ophthalmic artery. Lesion of the olfactory nerve causes anosmia (loss of smell). Fracture of the foramen spinosum damages the middle meningeal artery.

2. **The Answer is D.** If the trochlear nerve is injured, the patient is unable to turn the eyeball inferolaterally and has trouble going downstairs due to paralysis of the superior oblique muscle. Lesion of the oculomotor nerve causes ptosis due to paralysis of the levator palpebrae superioris, dilation of the pupil due to paralysis of the sphincter pupillae, loss of accommodation due to paralysis of ciliary muscles, and loss of pupillary light reflex due to loss of the efferent limb of the pupillary light reflex. Lesion of the optic nerve causes blindness. Lesion of the ophthalmic nerve causes loss of cutaneous sensation on the face above the upper eyelid. Lesion of the abducens nerve causes internal strabismus in which the eyeball turns medially.

3. **The Answer is D.** Accessory nerve passes through the posterior cervical triangle and is responsible for shrugging the shoulder and turn the head to the opposite side. The trigeminal nerve carries sensory fibers for the face and motor fibers for the muscles of mastication. The facial nerve carries motor fibers to the muscles of facial expression, secretomotor fibers to lacrimal, submandibular, sublingual, and nasal glands, and taste fibers from the anterior two-thirds of the tongue. The glossopharyngeal nerve conveys motor fibers to the stylopharyngeus muscle and taste fibers from the posterior one-third of the tongue. The hypoglossal nerve carries motor fibers for the muscles of tongue movement.

4. **The Answer is D.** The jugular foramen transmits cranial nerves, IX, X, and XI, along with the internal jugular vein. The cranial nerve V2 runs through the foramen rotundum. The cranial nerve VI passes through the superior orbital fissure. The cranial nerves VII and VIII courses through the internal auditory meatus. The cranial nerve XII passes through the hypoglossal canal.

5. **The Answer is C.** Lesion of sympathetic nerves in the cervical region results in a constricted pupil due to paralysis of the dilator pupillae. Internal strabismus is caused by a lesion of the abducens nerve. Lesion of the trochlear nerve results in difficulty going downstairs. Inability to close the eye is due to a lesion of the facial nerve. Lesion of the hypoglossal nerve causes deviation of the tongue toward the lesion side.

6. **The Answer is C.** Injury to the glossopharyngeal nerve causes paralysis of the stylopharoyngeus muscle, which is involved in swallowing, no general and taste sensation of the posterior one-third of the tongue, a lack of salivary secretion from the parotid gland due to parasympathetic nerve injury, and no visceral sensation from the carotid sinus and body. Lesion of the inferior alveolar nerve in the mandibular canal results in a lack of sensation to the canine and incisor teeth and the skin over the chin. Section of the zygomatic nerve causes a lack of lacrimal secretion because it carries postganglionic parasympathetic fibers from the pterygopalatine ganglion for lacrimal secretion. Tumor in the pituitary gland may damage the optic chiasma, resulting in the bitemporal hemianopia. Lesion of the hypoglossal nerve causes deviation of the tongue toward the injured side on protrusion.

7. **The answer is E.** The abducens nerve (CN VI) innervates the lateral rectus muscle, which abducts the eyeball. A lesion of the abducens nerve results in internal strabismus (medial deviation) and diplopia (double vision). Ptosis of the upper eyelid is caused by lesions of the oculomotor nerve or sympathetic nerve to the levator palpebrae superioris. Inability to dilate the

pupil is caused by a lesion of the sympathetic nerve to the dilator pupillae. External strabismus (lateral deviation) is caused by paralysis of the medial rectus muscle, which is innervated by the oculomotor nerve. Loss of visual accommodation is due to a lesion of parasympathetic nerve fibers to the ciliary muscle.

8. **The answer is A.** The anterior two-thirds of the tongue is innervated by the lingual nerve, a branch of the mandibular division of the trigeminal nerve (CN V). The posterior one-third of the tongue is innervated by the glossopharyngeal nerve (CN IX) for general and taste sensations. The facial nerve supplies taste fibers to the tongue through the chorda tympani but does not supply general sensation. The vagus nerve supplies general sensation and taste sensation to the epiglottis by way of the internal laryngeal branch. The hypoglossal nerve innervates the tongue muscles.

9. **The answer is B.** Lesion of the optic chiasma by a pituitary tumor results in bitemporal hemianopia resulting from loss in the nasal field of vision of both eyes. Lesion of the optic nerve causes blindness. A right perichiasmal lesion by an aneurysm of the internal carotid artery leads to right nasal hemianopia because of loss of vision in the nasal field of the right eye. Lesion of the right optic tract or optic radiation causes left homonymous hemianopia resulting from loss of the left half of the visual fields of both eyes. Aneurysms of both internal carotid arteries cause right and left perichiasmal lesions, leading to binasal hemianopia (loss of vision in the nasal fields of both eyes).

10. **The answer is C.** Damage to the parasympathetic ciliary ganglion and parasympathetic fibers in the short ciliary nerve impairs the ability to focus on close objects (accommodation). Because the patient can move his eyeballs normally, the oculomotor nerve is not damaged even if this nerve contains preganglionic parasympathetic fibers. The patient is able to see distant objects clearly because the long ciliary nerve also carries sympathetic fibers to the dilator pupillae. The ability to move the eyeball normally indicates that the oculomotor, trochlear, and abducens nerves are intact.

11. **The answer is C.** The vagus nerve innervates the musculus uvulae. A lesion of the vagus nerve causes deviation of the uvula toward the opposite side of the injury. Because her uvula deviates to the left on phonation, the right vagus nerve is damaged. Hoarseness is caused by a paralysis of the laryngeal muscles resulting from damage to skeletal motor fibers in the recurrent laryngeal branch of the vagus nerve.

12. **The answer is D.** A lesion of the hypoglossal nerve causes deviation of the tongue toward the injured side on protrusion. The lingual and glossopharyngeal nerves do not supply the tongue muscles.

13. **The answer is D.** The abducens nerve, which innervates the lateral rectus muscle, runs through the middle of the cavernous sinus. The other conditions listed do not injure the abducens nerve. A tumor in the pituitary gland may injure the optic chiasma, causing bitemporal hemianopsia.

14. **The answer is D.** The lingual nerve is joined by the chorda tympani in the infratemporal fossa. Therefore, the lingual nerve contains GSA fibers whose cell bodies are located in the trigeminal ganglion and SSA or taste fibers that have cell bodies located in the geniculate ganglion. In addition, the lingual nerve carries parasympathetic preganglionic GVE fibers that originated from the chorda tympani; the cell bodies are located in the superior salivatory nucleus in the pons. The chorda tympani and lingual nerves contain no fibers from the otic, submandibular, pterygopalatine, or dorsal root ganglia.

15. **The answer is E.** The oculomotor nerve carries parasympathetic fibers to the ciliary and sphincter pupillae ciliary muscles; thus, a lesion of the oculomotor nerve leads to ciliary muscle paralysis and a dilated pupil. The abducens nerve supplies the lateral rectus, which is an abductor of the eye. The levator palpebrae superioris inserts on the tarsal plate in the upper eyelid, which is innervated by sympathetic fibers. Thus, a lesion of the oculomotor nerve does not cause complete ptosis. The secretomotor fibers for lacrimal secretion come through the pterygopalatine ganglion. Thus, severance of the oculomotor nerve has no effect on lacrimal secretion.

16. **The answer is C.** The afferent limb of the corneal reflex arc is the nasociliary nerve, and its efferent limb is the facial nerve. The other nerves are not involved in the reflex arc. The opening of the eye is conducted by the oculomotor nerve, but it is not a part of the corneal reflex.

17. **The answer is E.** The nerve of the pterygoid canal (Vidian nerve) contains taste SVA fibers from the palate, GVA fibers, postganglionic sympathetic fibers, and preganglionic parasympathetic fibers.

18. **The answer is D.** The secretomotor fibers to the lacrimal gland are parasympathetic fibers that run in the facial, greater petrosal, Vidian (nerve of the pterygoid canal), maxillary, zygomatic (of maxillary), zygomaticotemporal, and lacrimal (terminal portion) nerves. The lesser petrosal nerve carries secretomotor (preganglionic parasympathetic) fibers to the parotid gland. The deep petrosal nerve contains postganglionic sympathetic fibers. The zygomatic branch of the facial nerve supplies the facial muscles.

19. **The answer is C.** The maxillary nerve runs through the foramen rotundum; the ophthalmic nerve runs through the supraorbital fissure; the mandibular nerve passes through the foramen ovale; the optic nerve runs through the optic canal; and the trochlear nerve passes through the superior orbital fissure.

20. **The answer is B.** Muscles derived from the second (hyoid) pharyngeal arch are innervated by the facial nerve. Muscles derived from the first (mandibular) pharyngeal arch are innervated by the mandibular division of the trigeminal nerve. A muscle derived from the third pharyngeal arch is innervated by the glossopharyngeal nerve. Muscles derived from the fourth and sixth pharyngeal arches are innervated by the vagus nerve. Muscles of myotome origin that shrug shoulder and turn head are innervated by the accessory nerve.