The Cranial Nerves

Origins, Pathways
& Basic Applied Anatomy

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Manuscript designed by Naeem Majeed, KEMU ***NM***

Compiled & Improved by Saba Fatima, KEMU

Reviewed & Corrected by Hina Fatima, RMC (**HYNA**)

THE CRANIAL NERVES

(Origin, Pathways & Applied Anatomy)

There are twelve cranial nerves, which leave the brain and pass through foramina in the skull. All the nerves are distributed in the head and neck except the tenth, which also supplies structures in the thorax and abdomen.

The cranial nerves are named as follows;

I. Olfactory
II. Optic
III. Oculomotor
IV. Trochlear
V. Trigeminal
VI. Abducent
VII. Facial
VIII. Vestibulocochlear
IX. Glossopharyngeal
X. Vagus
XI. Accessory
XII. Hypoglossal

The olfactory, optic and vestibulocochlear nerves are entirely sensory; the oculumotor, trochlear, abducent, accessory and hypoglossal nerves are entirely motor, and the remaining nerves are mixed nerves. The MOTOR or EFFERENT fibers of cranial nerves arise from groups of neurons in the brain, which are their *nuclei of origin.* The SENSORY or AFFERENT fibers of the nerves arise neurons situated outside the brain, grouped to form ganglia or sited in peripheral sensory organs. Their processes enter the brain and grouped to form *nuclei of termination.*

GENERAL PLAN OF CRANIAL NERVES

NERVE	FORAMEN(A)	GENERAL DESTINATION	SENSORY FUNCTIONS	SOMATIC MOTOR FUNCTIONS	AUTONOMIC MOTOR FUNCTIONS
I Olfactory (Sensory)	Olfactory Foramina	Sensory neurons: olfactory bulbs	Olfaction (special sensory)		
II Optic (Sensory)	Optic Canal	Sensory neurons: optic chiasm and midbrain	Vision (special sensory)		
III Oculomotor (Motor)	Superior orbital fissure (middle part)	Motor neurons: muscles of the eye		Superior, inferior, and medial rectus muscles, inferior oblique and levator palpebrae superioris	Circular muscles (pupil constriction), ciliary muscle (accommodation)
IV Trochlear (Motor)	Superior orbital fissure	Motor neurons: muscles of the eye		Superior oblique muscle	
V Trigeminal (Mixed)	Ophthalmic Branch: Superior orbital fissure Maxillary Branch: Foramen rotundum; Mandibular Branch: Foramen ovale	Sensory Neurons: pons Motor Neurons: muscles of mastication	Ophthalmic branch: nasal cavity, skin of forehead, upper eyelid, eyebrow, nose. Maxillary branch: lower eyelid, upper lip, gums, teeth, cheek, nose palate, pharynx Mandibular branch: lower gums, teeth, lips, palate, tongue	Mandibular branch: Temporalis and masseter muscles	
VI Abducens (Motor)	Superior orbital fissure	Motor Neurons: muscles of the eye		Lateral rectus muscle	
VII Facial (Mixed)	Internal acoustic meatus and stylomastoid foramen (via facial canals)	Sensory Neurons: pons Motor Neurons: Muscles of facial expression, lacrimal gland, submandibular and sublingual salivary glands, mucous membranes	Taste from anterior 2/3's of tongue (special sensory)	Facial, scalp and neck muscles	Lacrimal and submandibular and sublingual salivary glands, mucous membranes of nose and palate
VIII Vestibulocochlear (Sensory)	Internal acoustic meatus	Sensory Neurons: Medulla, pons, cerebellum, thalamus	Vestibular branch: equilibrium Cochlear branch: hearing (special sensory)		
IX Glossopharyngeal (Mixed)	Jugular foramina	Sensory Neurons: medulla Motor Neurons: muscles of speech and swallowing, parotid salivary glands	Taste from posterior 1/3 or tongue (special sensory) Pharynx, posterior tongue, chemoreceptors and baroreceptors	Muscles of the pharynx and tongue (speech and swallowing)	Saliva production and salivation
X Vagus (Mixed)	Jugular foramina	Sensory Neurons: medulla Motor Neurons: throat, heart, lungs, abdominal viscera	Skin at back of ear, in external acoustic meatus, part of tympanic membrane, larynx, trachea, esophagus, thoracic and abdominal viscera, baroreceptors, chemoreceptors, taste from epiglottis and pharynx (special sensory)	Swallowing, coughing, voice production via pharyngeal muscles	Smooth muscle contraction of the abdominal viscera, visceral gland secretions, Relaxation of airways and decreased heart rate
XI Accessory (Motor)	Jugular foramina	Motor Neurons: Soft palate, throat, some necks muscles		Swallowing and head movement (via trapezius and sternocleidomastoid)	
XII Hypoglossal (Motor)	Hypoglossal canal (in occipital bone)	Motor Neurons: Tongue muscles		Speech and swallowing via muscles of the tongue	

OLFACTORY NERVE:

Olfactory nerve bundles (CN-I) serving the SENSE OF SMELL have their cells of origins in the olfactory mucosa in the nasal cavity; this olfactory region comprises the mucosa of the superior nasal concha and the opposite part of the nasal septum.

Bipolar cells in neuro epithelium (receptors) → 20 Olfactory nerve fibers — *Cribriform Plate* — *Dura Arachnoid* —

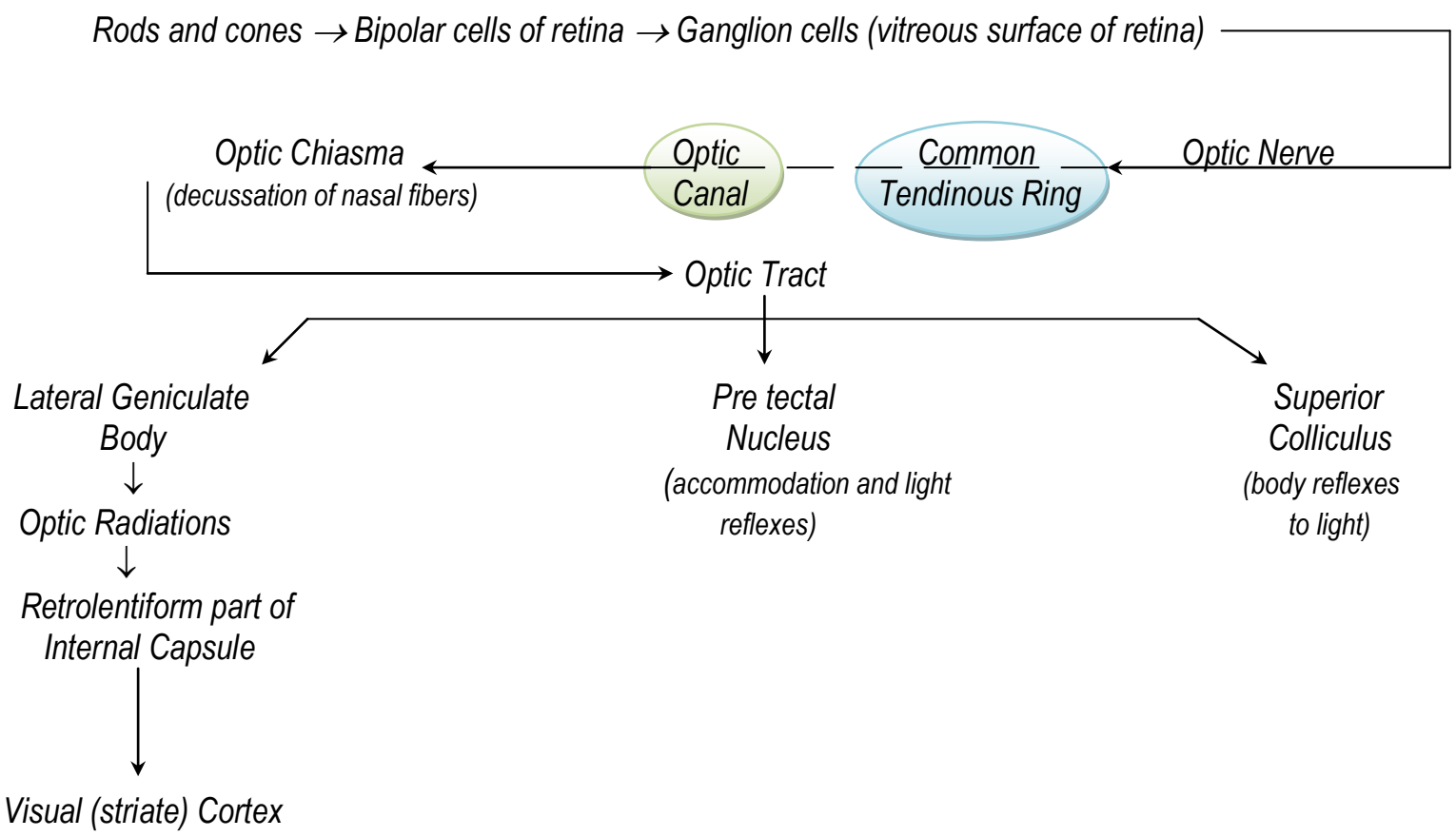
Olfactory bulb ← *Olfactory tract* ← *Anterior perforated substance And uncus*

Bypass the thalamus → Activates cortex, Brainstem & Hypothalamic Nuclei

APPLIED ANATOMY: In severe head injuries involving the anterior cranial fossa, the olfactory bulb may be separated from olfactory nerves or the nerves may be torn, producing *ANOSMIA*… loss of olfaction. Fractures may involve the meninges admitting CSF into the nose.

OPTIC NERVE:

The optic nerve (CN-II) mediating VISION is distributed to the eyeball. Its afferent fibers originate in the retinal ganglionic layer. Developmentally, both the optic nerve & retina are outgrowths of brain. Optic nerve fibers from the retina converge on the optic disc, pierce near the posterior pole of the eyeball where four recti and ciliary vessels & nerves surround it. In the optic canal, it is related superomedially to the ophthalmic artery & nasociliary nerve.



APPLIED ANATOMY: Lesions of the optic pathway may have many pathological causes. Expanding tumors of the brain & the meninges and cerebrovascular accidents are commonly responsible. Lesions of the optic nerve may be at different levels with different affects, as follows:

a. Complete lesion of the optic nerve of one side leads to complete blindness in the corresponding eye.
b. Compression of optic chiasma causes bitemporal hemianopia because the nasal fibers from both sides are interrupted.
c. Lesion of the optic tract of one side leads to corresponding nasal & contralateral temporal hemianopia.
d. Lesion of the optic radiation of one side leads to corresponding nasal & contralateral temporal hemianopia.
e. Circumferential blindness is caused most commonly by optic neuritis.

OCULOMOTOR NERVE:

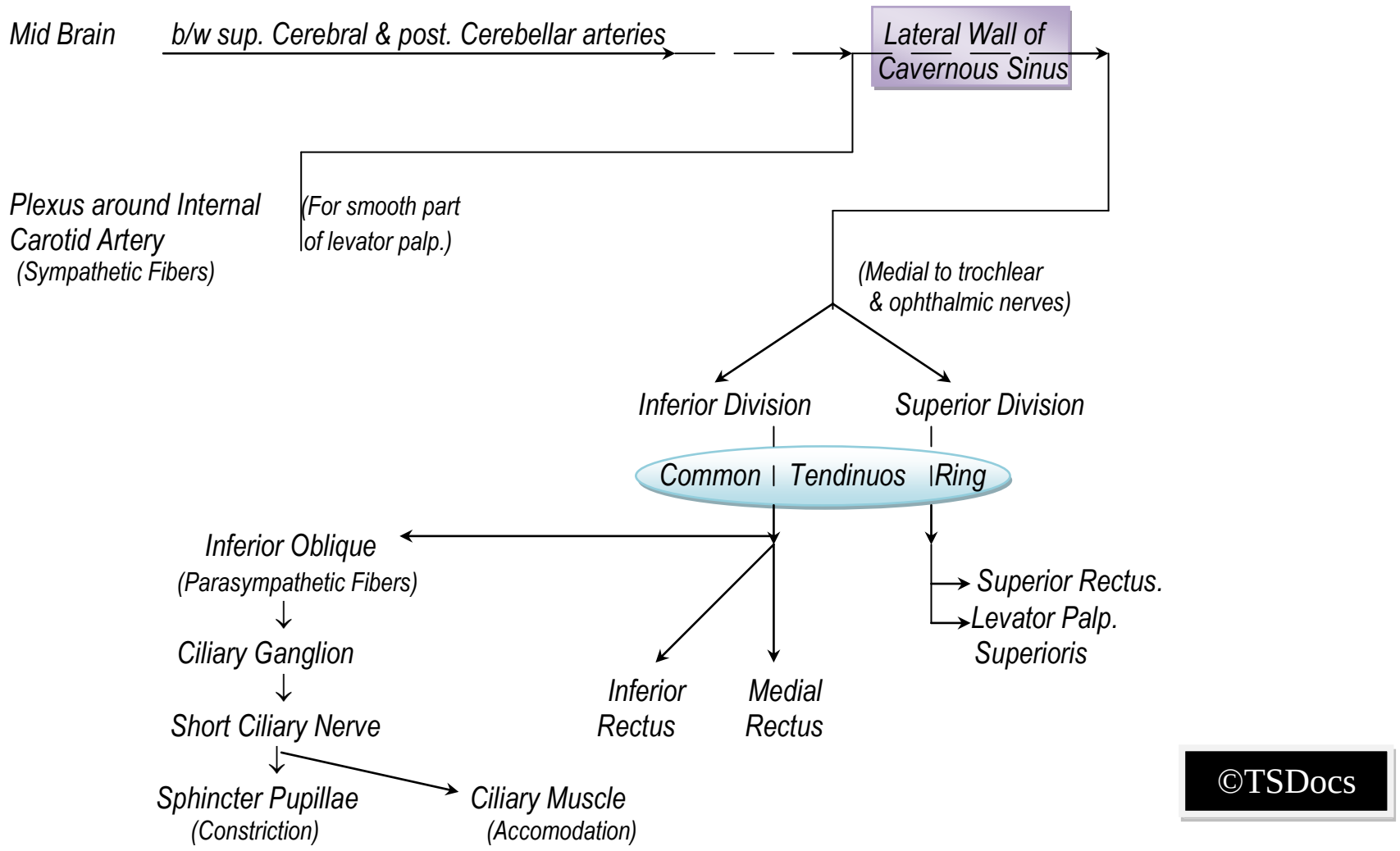
The oculomotor nerve (CN-III) supplies all the extraocular muscles of the eyeball except lateral rectus & superior oblique. Besides it also supplies autonomic fibers to sphincter pupillae & ciliaris muscle.

NUCLEI:

Somatic Efferent: Oculomotor nucleus at midbrain level with superior colliculus for superior rectus, medial rectus, inferior rectus, Inferior oblique & levator palpabrae superioris.
General Visceral Efferent: Edinger Westphal nucleus for sphincter pupillae & ciliary body via ciliary ganglion.

INTRACRANIAL COURSE: From the nucleus the fibers pass forwards through the tegmentum, red nucleus & the medial part of the substantia nigra, curving with a lateral convexity to emerge from the sulcus on the medial side of cerbral peduncle.

EXTRACRANIAL COURSE:



APPLIED ANATOMY: Oculomotor nerve may undergo complete or incomplete lesions.

⇒ Complete lesions of oculomotor nerve leads to

a. Ptosis - drooping of the eyelid due to paralysis of levator palpabrae.
b. External strabismus due to unopposed action of lateral rectus & superior oblique.
c. Pupillo-dilatation due to paralysis of sphincter pupillae.
d. Loss of accommodation & of light reflex due to paralysis of sphincter pupillae & ciliaris.
e. Diplopia – the false image being the higher.

⇒ Incomplete lesions of oculomotor nerve are common and may spare the extraocular or intraocular muscles.

a. The condition in which the innervation of extraocular muscles is spared with selective loss of autonomic innervation is called *INTERNAL OPHTHALMOPLEGIA*.
b. The condition in which the intraocular muscles are spared with paralysis of extraocular muscles is called *EXTERNAL OPHTHALMOPLEGIA*.

TROCHLEAR NERVE:

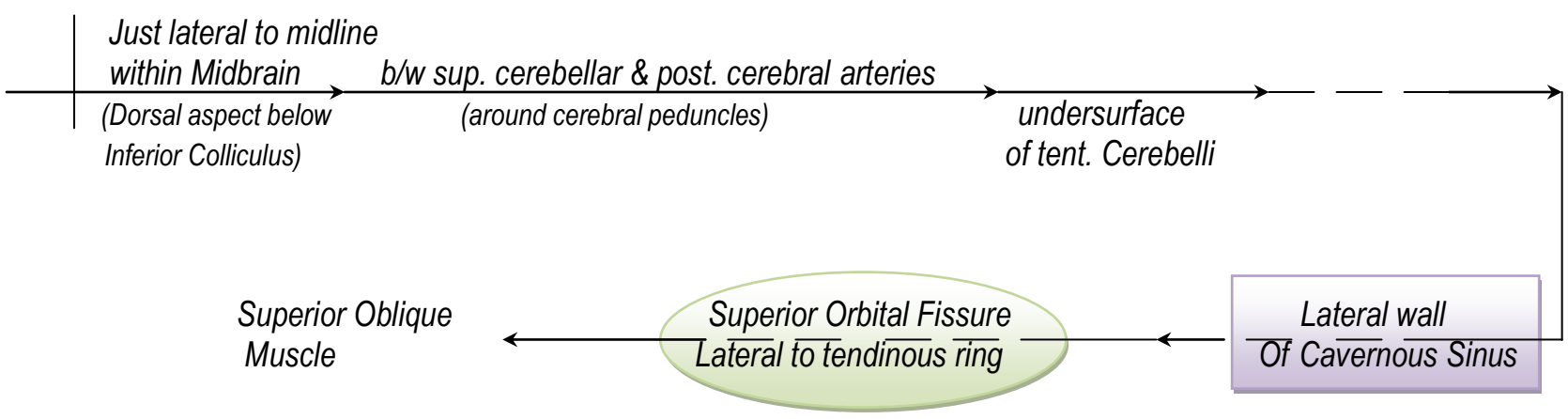
The trochlear nerve (CN-IV), the thinnest cranial nerve, supplies the extraocular superior oblique muscle.

NUCLEUS:

Somatic Efferent: Trochlear Nucleus at the level of inferior colliculus in mid brain for superior oblique.

INTRACRANIAL COURSE: After leaving its nucleus, the trochlear nerve fibers first descend laterally through the tegmentum and turning posteriorly round the central gray matter into the anterior medullary velum. Here it decussates with the fellow of opposite side, crossing the midline to emerge from the dorsal aspect of the velum. IT IS THE ONLY CRANIAL NERVE TO EMERGE DORSALLY FROM THE BRAINSTEM.

EXTRACRANIAL COURSE:



APPLIED ANATOMY: The conditions most commonly affecting the trochlear nerve include stretching or bruising as a complication of head injuries, cavernous sinus thrombosis & aneurysm of the internal carotid artery. As a result of such injuries, interruption of the trochlear nerve paralyses the superior oblique, limiting inferolateral ocular movement; the affected eye rotates medially, producing *DIPLOPIA.* There is also some degree of extorsion, because the superior oblique, which normally produces intorsion, is not available. To compensate for this, the patient characteristically tilts the head towards the opposite shoulder.

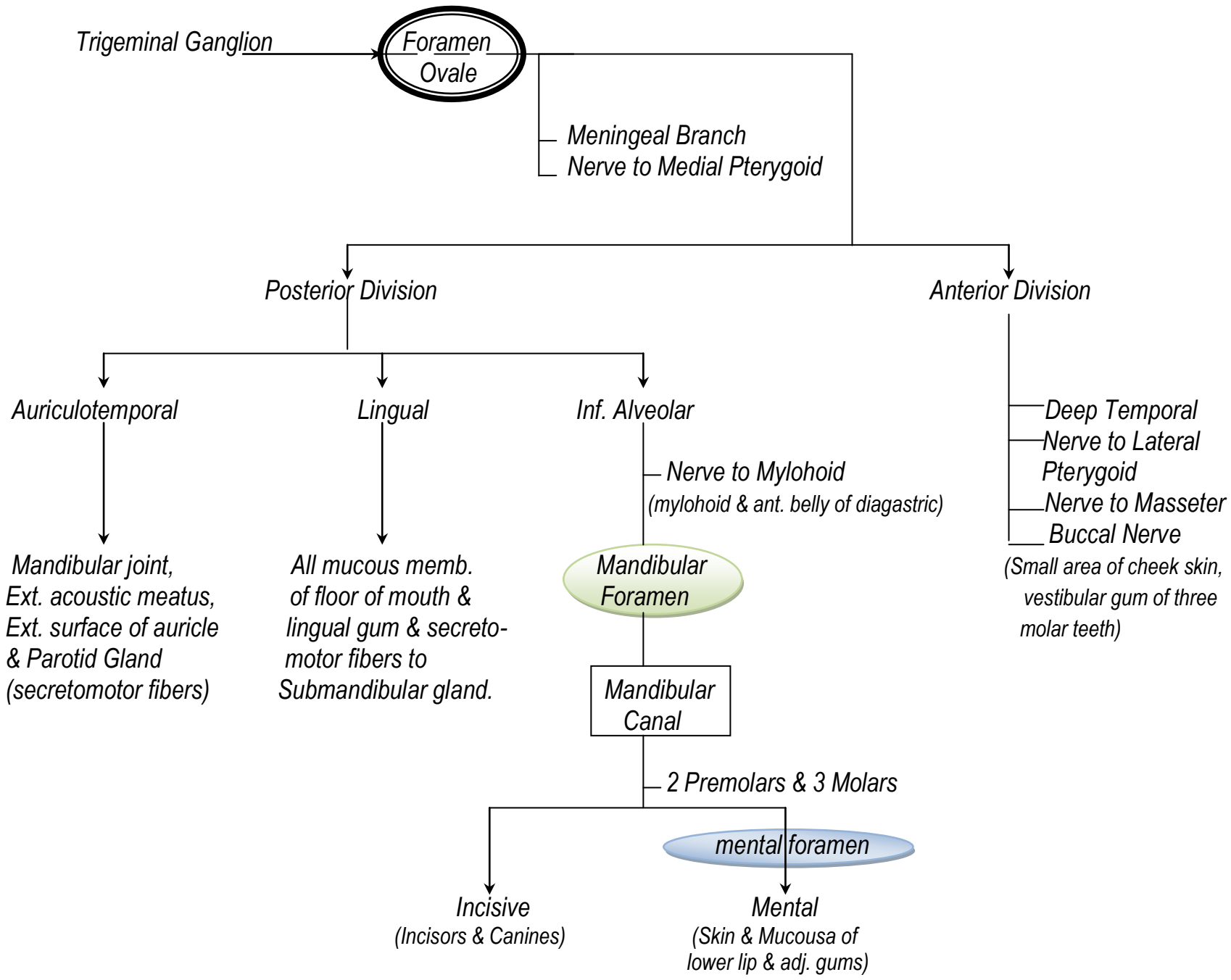
TRIGEMINAL NERVE:

The trigeminal (CN-V), the largest cranial nerve, is the sensory supply to face, the greater part of the scalp, the teeth, the oral & nasal cavities and the motor supply to the masticatory & some other muscles. It also contains proprioceptive fibers from the masticatory & extraocular muscles. It has three divisions *OPHTHALMIC, MAXILLARY & MANDIBULAR.* It emerges from pons as a larger sensory & smaller motor root. Fibers in the *sensory root* are mainly axons of cells in the ***trigeminal ganglion***, which occupies trigeminal cave. The neuritis of the unipolar cells in ganglion divides into peripheral & central processes. The peripheral branches constitute the *ophthalmic, maxillary* & sensory parts of the *mandibular nerve.* The central branches constitute the fibers of the sensory root, which ends in the pons.

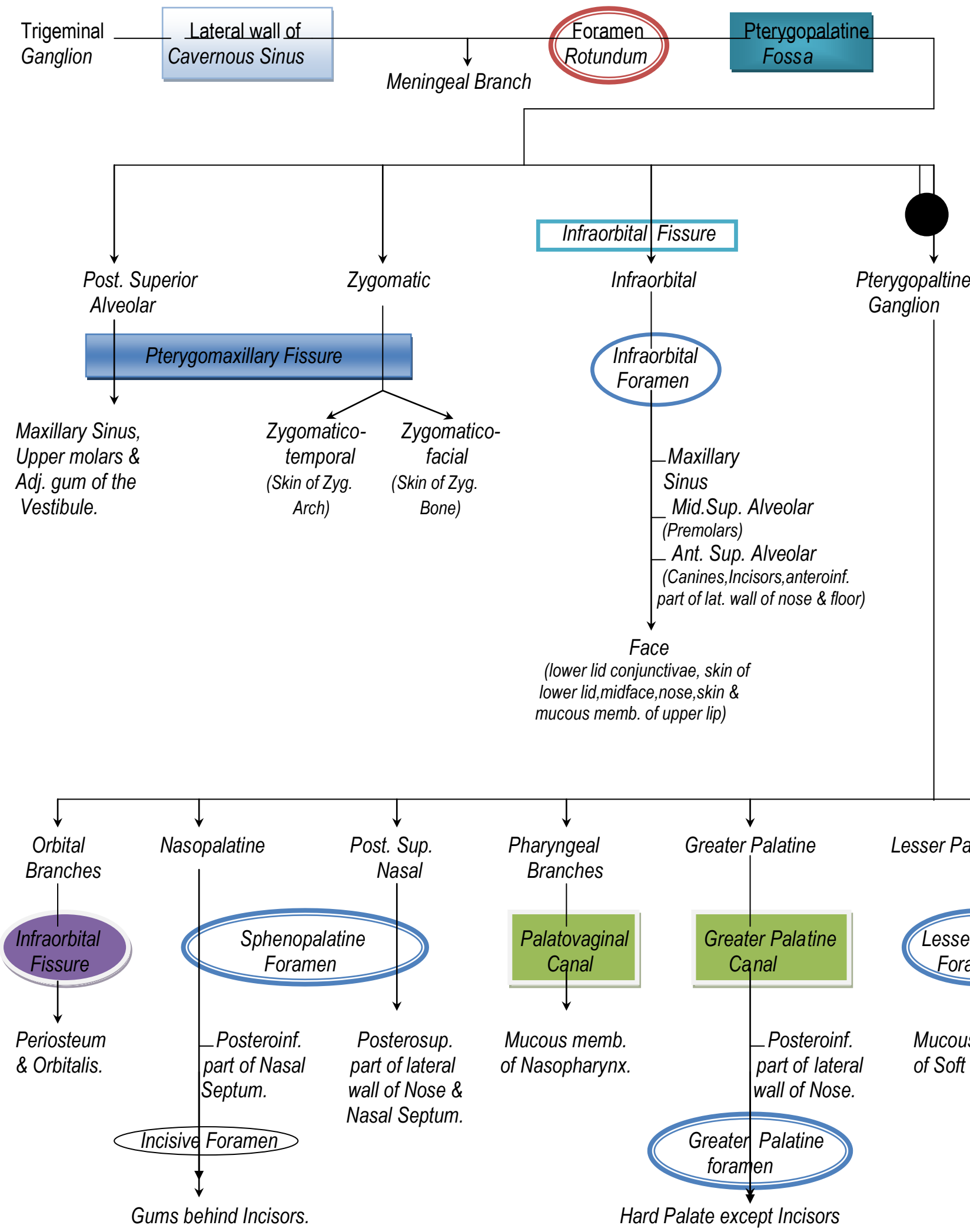
NUCLEI: There are four nuclei, one motor & three sensory.
Branchial Efferent: Motor nucleus of trigeminal in upper pons, for masticatory muscles, mylohyoid & tensor palati.
Somatic Efferent: Three sensory nuclei of trigeminal continuous throughout the brainstem & extending into upper spinal cord.

- Mesencephalic nucleus in the mid brain, for propioception from muscles of mastication, face, tongue & orbit.
- Main sensory nucleus in upper pons, for touch from trigeminal area.
- Spinal nucleus in lower pons, medulla & upper cervical spinal cord, for pain and temp from trigeminal area.

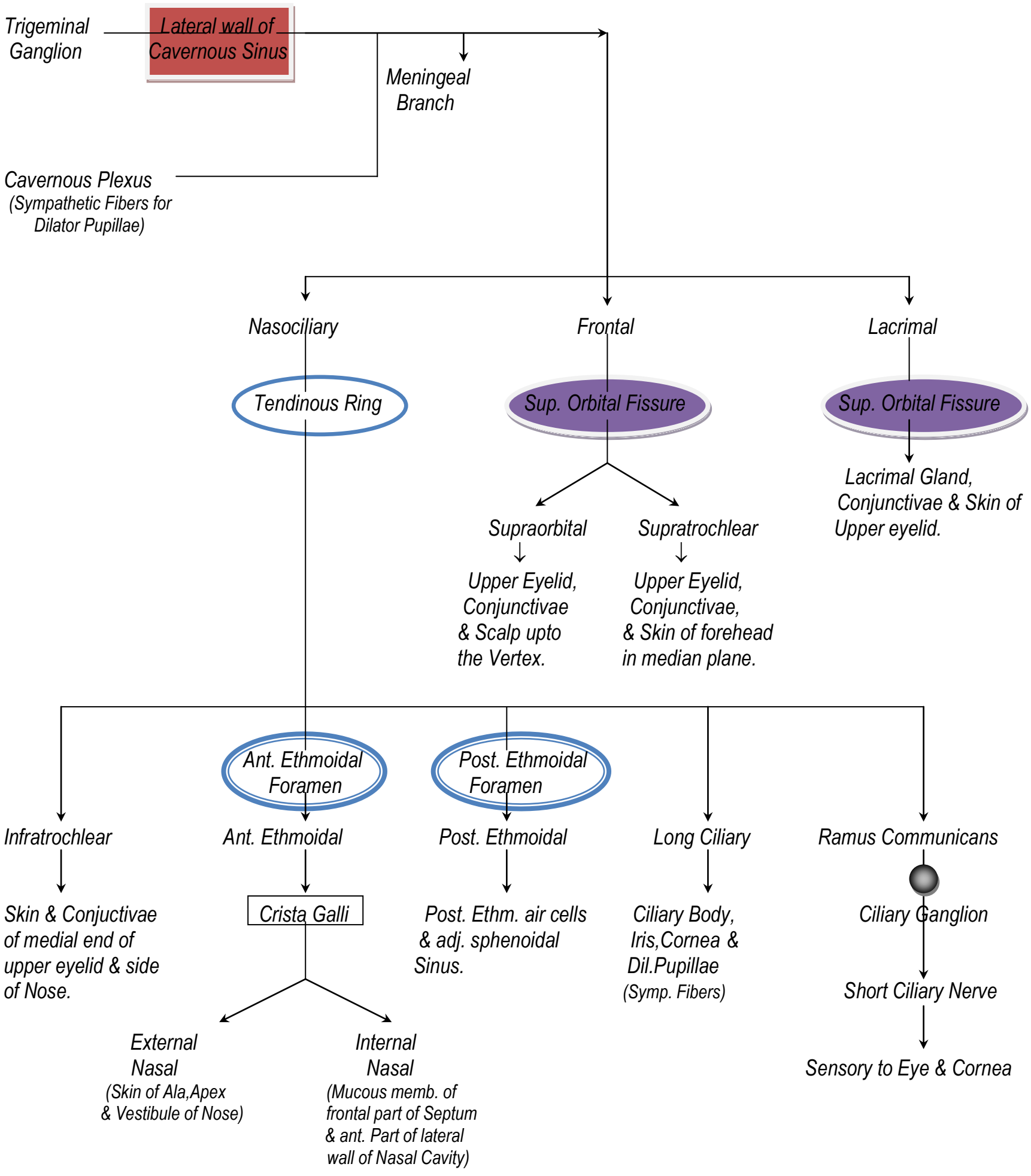
MANDIBULAR DIVISION OF TRIGEMINAL NERVE:



MAXILLARY DIVISION OF TRIGEMINAL NERVE:



OPHTHALMIC DIVISION OF TRIGEMINAL NERVE:



APPLIED ANATOMY OF TRIGEMINAL NERVE: A lesion of the whole trigeminal nerve causes anaesthesia of the anterior half of the scalp, of the face (except a small area near the angle of mandible), of the cornea & conjunctiva, the mucosae of the nose, mouth and presulcal part of the tongue. Paralysis and atrophy occur in the muscles supplied by the nerve also.

TRIGEMINAL NEURALGIA characterized by pain in the distribution of branches of the trigeminal nerve, is the most common condition affecting the sensory part of the nerve.

⇒ With the *maxillary nerve* affected, the pain is usually felt deeply in the face & nose between the mouth and orbit. The cause of maxillary neuralgia is often neoplasms & empyema of the maxillary sinus.

⇒ With the *mandibular nerve* affected, the pain is usually felt from mouth upto the ear and the temporal region. The most common cause is carious mandibular tooth or an ulcer & carcinoma of tongue.

⇒ With the *ophthalmic nerve* affected, the pain is usually felt in supraorbital region and is often associated with glaucoma or with frontal or ethmoidal sinusitis.

ABDUCENS NERVE:

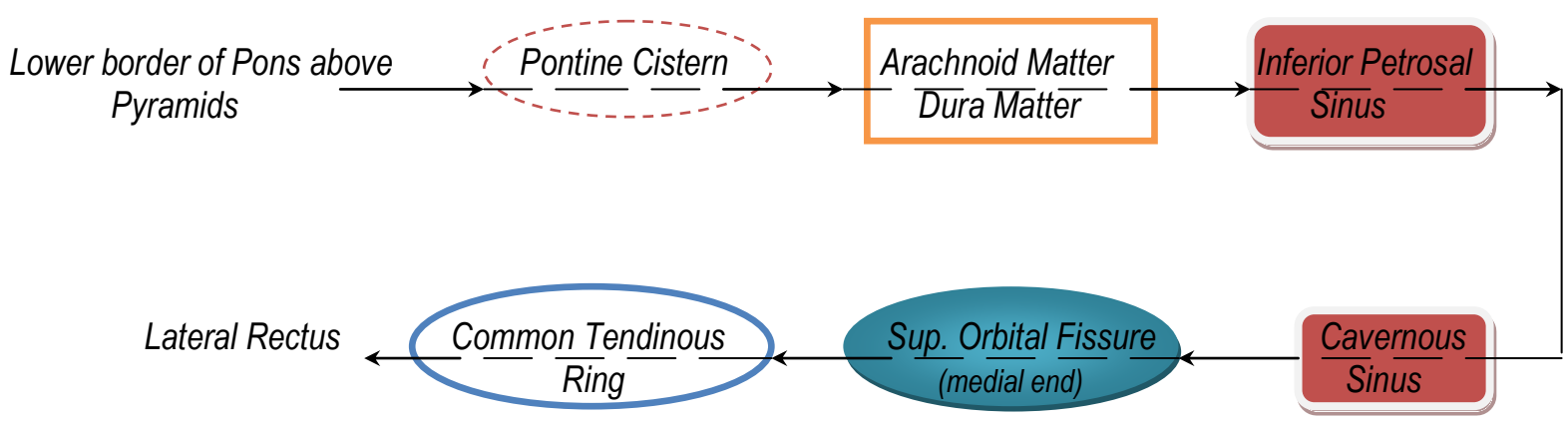
The abducens nerve (CN-VI) supplies only the lateral rectus muscle of eyeball.

NUCLEUS:

Somatic Efferent: Abducent nucleus in pons deep to facial colliculus in floor of 4th ventricle for lateral rectus.

INTRACRANIAL COURSE: The fibers of abducens nerve descend ventrally through the pons, emerging in the sulcus between the caudal border of the pons and the superior end of the pyramid of the medulla oblongata.

EXTRACRANIAL COURSE:



APPLIED ANATOMY: In a lesion of the abducens nerve, the patient cannot turn the eye laterally. When the patient is looking ahead, the lateral rectus is paralyzed and the unopposed medial rectus pulls the eyeball medially, causing *INTERNAL STRABISMUS.* There is diplopia. The long course of the nerve through the cisterna pontis and its sharp bend over the petrous temporal bone make the nerve liable to damage in conditions producing raised intracranial pressure. However the most common causes of lesions include damage due to head injuries, cavernous sinus thrombosis or aneurysm of the internal carotid artery.

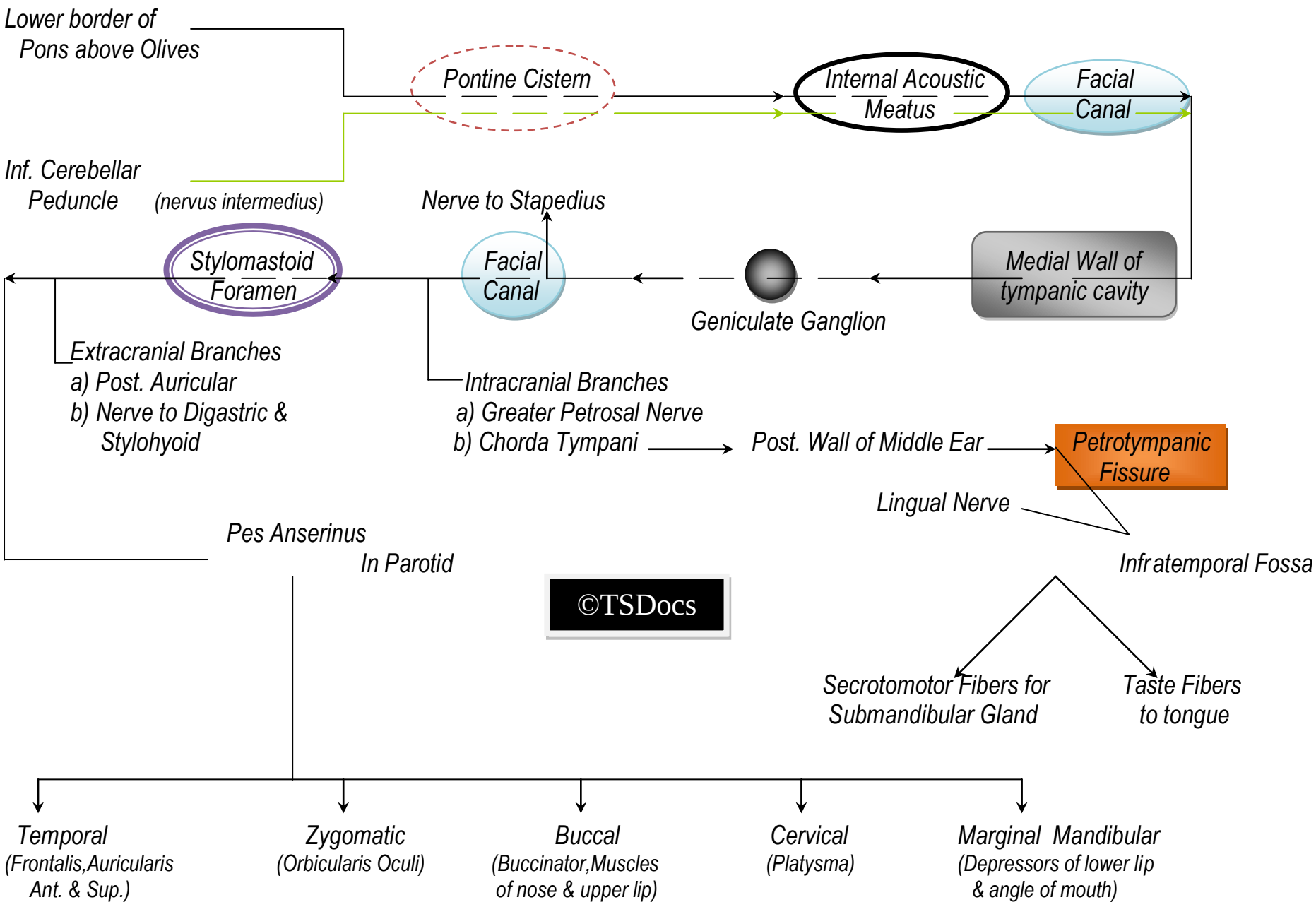
FACIAL NERVE:

The facial nerve (CN-VII), the main motor supply of face consists of a motor & sensory (nervus intermedius) roots. The two roots emerge at the caudal border of the pons. The motor root mainly supplies muscles of face, stapedius & stylohyoid. The sensory root conveys from the chorda tympani gustatory fibers from the presulcal area of tongue, and from the palatine & greater petrosal nerves, taste fibers from the soft palate; it also carries preganglionic innervation of the submandibular & sublingual salivary glands, lacrimal glands and glands of nasal & palatine mucosae.

NUCLEUI:

Branchial Efferent: Facial nerve nucleus in pons for facial muscles, stapedius and stylohyoid.
General Visceral Efferent: Sup. Salivatory nucleus adjacent to facial nucleus, secretomotor to pterygopalatine & submandibular ganglion for lacrimal & salivary glands.
Special Visceral Afferent: Nucleus of Tractus Solitarius lateral to dorsal nucleus of Vagus in upper medulla, for taste fibers of Chorda Tympani & Greater Petrosal Nerve.

COURSE:



APPLIED ANATOMY: The facial nerve may be injured or become dysfunctional anywhere along its course from the brainstem to the face. The paralysis may be *supranuclear* or *infranuclear.*

⇒ Supranuclear facial paralysis, involving upper motor neurons pathway is usually a part of hemiplegia. It involves paralysis of the lower part of the face but not the upper (forehead and orbicularis oculi) because the facial nerve nucleus innervating the upper part of face receives fibers from cerebral cortex of both sides whereas the lower part innervating the lower part of the face receives contralateral fibers. However emotional movements of the lower face, as in smiling and laughing, are still possible (presumably there is an alternative pathway from the cerebrum).

⇒ Infranuclear lesions vary in its effects depending on the site of lesion. Due to the anatomical location of facial nerve, neighbouring structures are inevitably involved.

a. If the facial nucleus or facial pontine fibers are involved, there may be damage to the abducent nucleus (paralysis of lateral rectus), motor trigeminal nucleus may be involved (paralysis of masticatory muscles), principal sensory nucleus and spinal trigeminal nucleus may also be involved (sensory loss of face).
b. Lesions in the posterior cranial fossa or internal acoustic meatus may involve vestibulocochlear nerve, resulting in loss of taste from anterior part of tongue with ipsilateral deafness & facial paralysis.
c. Lesions of facial nerve in the facial canal may involve nerve to stapedius causing excessive sensitivity to sound in one ear.
d. When damage is in the petrous temporal bone, chorda tympani is usually involved resulting in loss of taste from anterior two thirds of the tongue.

BELL'S PALSY: It is caused due to inflammation of facial nerve near the stylomastoid foramen or compression of its fibers near facial canal or stylomastoid foramen. If the lesion is complete, the facial muscles are all equally affected, with the following complications:

*There is facial asymmetry and the affected side is immobile.
*The eyebrows are drooped, wrinkles are smoothed out, and the palpebral fissure is widened by the unopposed action of levator palpebrae.
*The lips remain in contact and cannot be pursued; in attempting to smile the angle of the mouth is not drawn up on the affected side, the lips remaining nearly closed.
*Food accumulates in the cheek, from paralysis of buccinator, and dribbles, or is pushed out between the paralysed lips.
*Platysma and the auricular muscles are paralysed.
*Tears will flow over the lower eyelid and saliva will dribble from the corner of the mouth.

VESTIBULOCOCHLEAR NERVE:

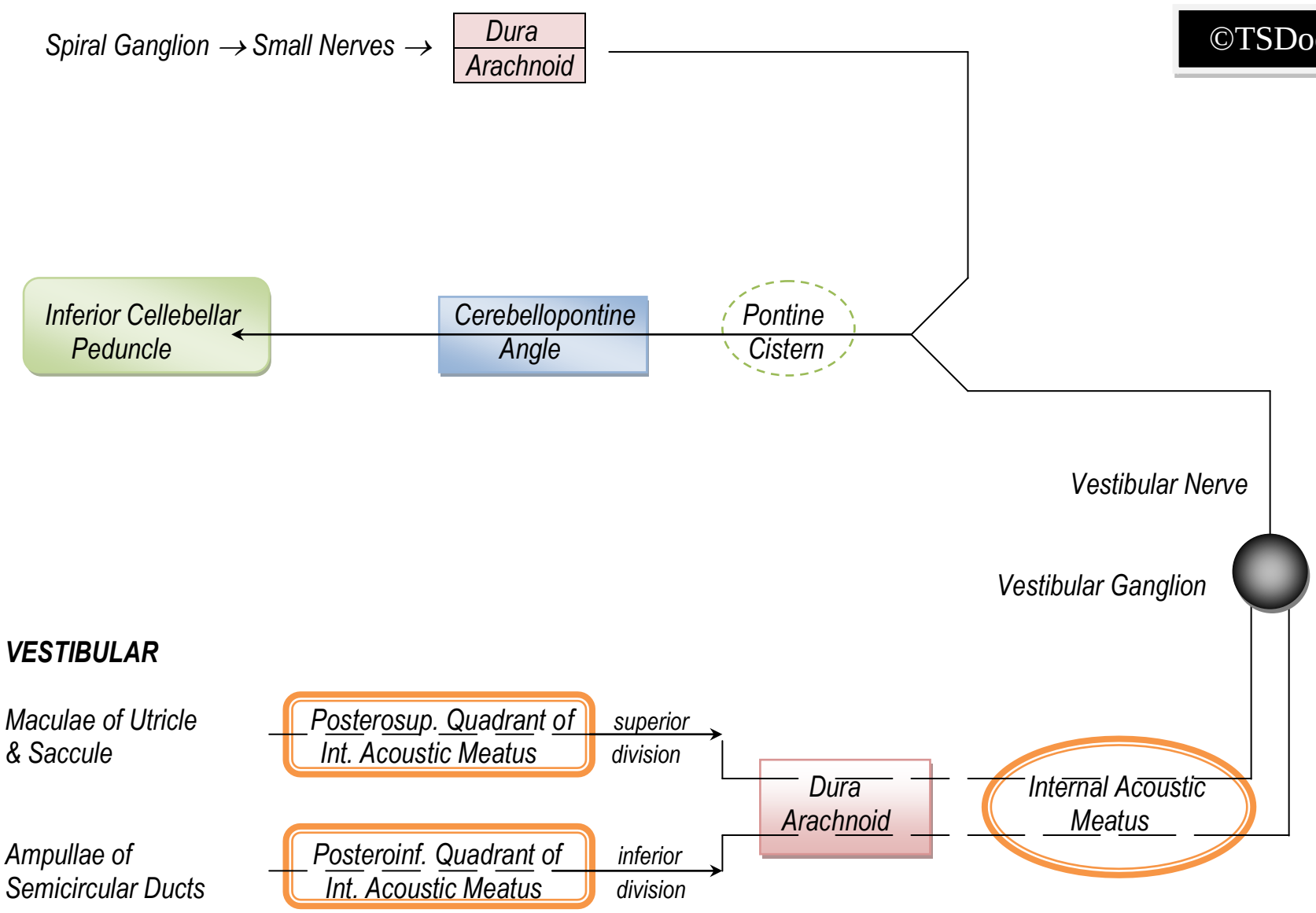
The vestibulocochlear nerve (CN-VIII), is main sensory supply of internal ear. It has two major sets of fibers, one set from the *vestibular nerve,* concerned with equilibration and arising from neurons in the vestibular ganglion in the outer part of internal acoustic meatus. The other set of fibers form the *cochlear nerve*, arising from the neurons in the spiral ganglion of the cochlea. The nerve emerges in the groove between the pons and the medulla oblongata, behind the facial nerve.

NUCLEI:

Special Somatic Afferent: Two cochlear nuclei in Inf. Cerebellar Peduncle for HEARING.
Special Somatic Afferent: Four vestibular nuclei in Pons & Medulla for EQUILIBRIUM.

COURSE AND PATHWAY:

COCHLEAR



APPLIED ANATOMY OF VESTIBULAR NERVE: Disturbances of vestibular nerve function include giddiness (*VERTIGO)* and *NYSTAGMUS*. Vestibular nystagmus is an uncontrollable rhythmic oscillation of the eyes. This form of nystagmus is an essentially a disturbance in the reflex control of the extraocular muscles, which is one of the functions of the semicircular canals. The causes of the vertigo include diseases of labyrinth, lesions of the vestibular nerve & the cerebrellum, multiple sclerosis, tumours and vascular lesions of the brainstem.

APPLIED ANATOMY OF COCHLEAR NERVE: Disturbances of the cochlear nerve function produce *DEAFNESS* and *TINNITUS.* Loss of hearing may be due to a defect of the auditory conducting mechanism in the middle ear, damage to the receptor cells in the spiral organ of Corti in the cochlea, lesions of the cochlear nerve due to acoustic neuroma and trauma, or lesion of the cerebral cortex of temporal lobe due to multiple sclerosis.

GLOSSOPHARYNGEAL NERVE:

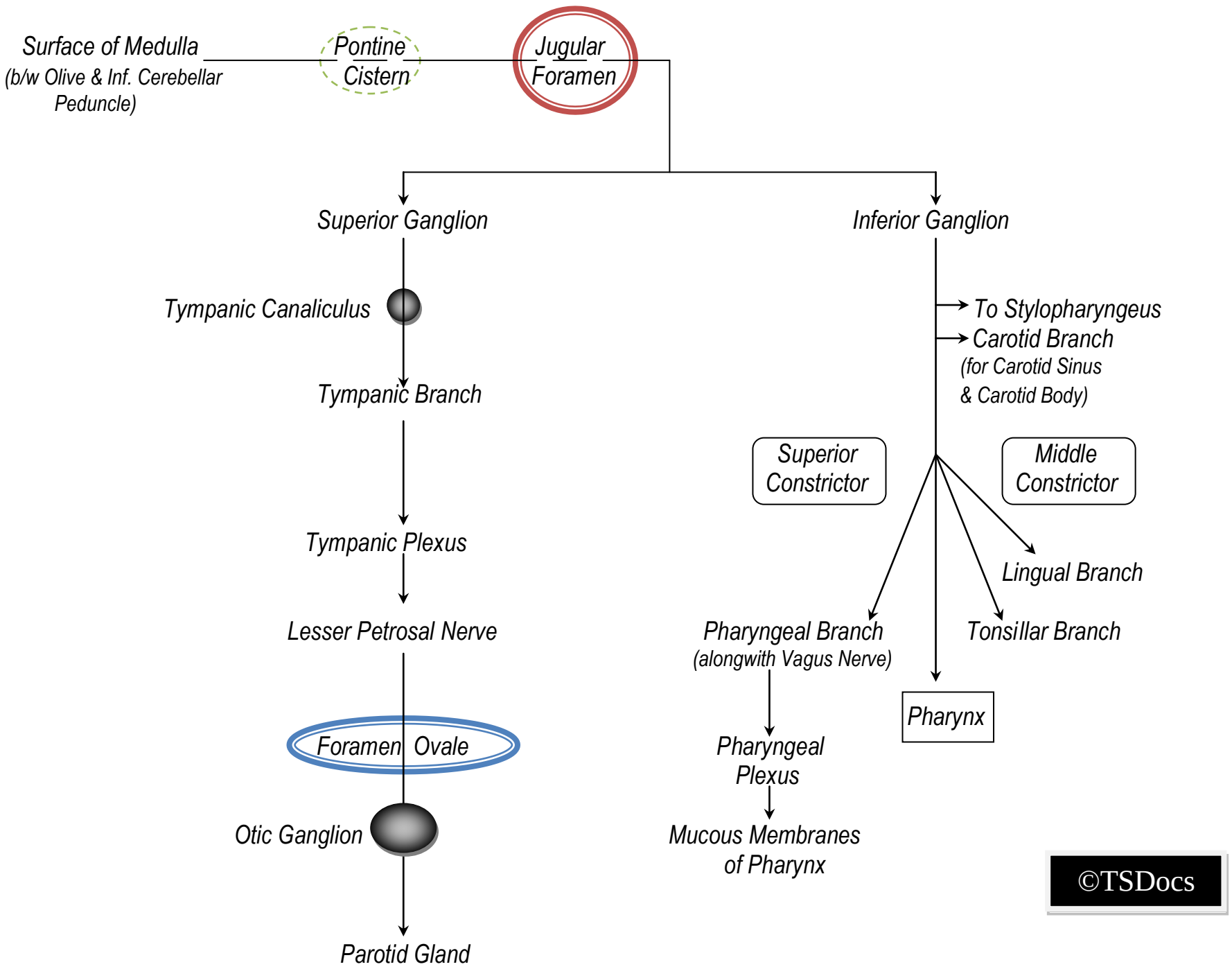
The glossopharyngeal nerve (CN-IX), is both motor and sensory, supplying motor fibers to the stylopharyngeus, parasympathetic fibers to the parotid gland and sensory fibers to the tonsils, pharynx and posterior part of the tongue, also gustatory to this part of the tongue.

NUCLEI:

Branchial Efferent: Nucleus Ambiguus in upper Medulla for Stylopharyngeus.
General Visceral Efferent: Inferior Salivatory Nucleus for Otic Ganglion.
General & Special Visceral Afferent: Nucleus of Tractus Solitarius for Taste fibers, Baroreceptors & Chemoreceptors of carotid Body.
Somatic Afferent: Spinal Nucleus of Trigeminal for ordinary sensations from Mucous Membranes of Tongue, Palate, Pharynx.

INTRACRANIAL COURSE: In the intracranial course, the fibers of the nerve pass forwards and laterally, between the olivary nucleus and the inferior cerebellar peduncle, through the reticular formation of the medulla. It is attached by 3 to 4 filaments, to the posterolateral sulcus of medulla, just above the vagus.

EXTRACRANIAL COURSE:



APPLIED ANATOMY: Isolated glossopharyngeal nerve lesions are extremely rare, as the last four cranial nerves are not often damaged and even if they are, they are commonly affected together e.g. by a tumour in posterior cranial fossa.

VAGUS NERVE:

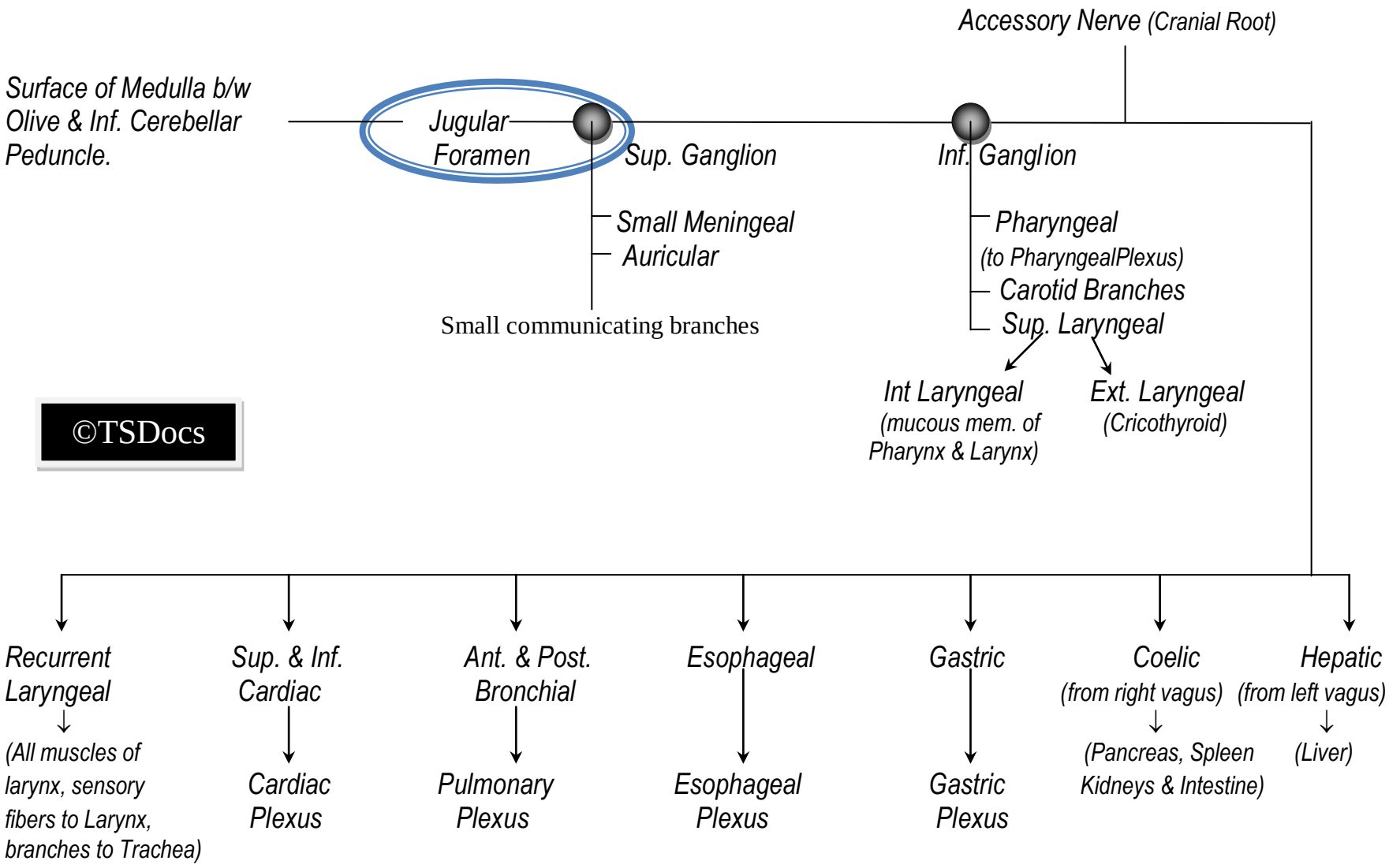
The vagus nerve (CN-X), contains motor and sensory fibers and has a more extensive course and distribution than any other cranial nerve, traversing the neck, thorax and abdomen.

NUCLEI:

Branchial Efferent: Nucleus Ambiguus in upper Medulla for Palate, Pharynx, Larynx & Upper Esophagus.
General Visceral Efferent: Dorsal Motor Nucleus of Vagus for Cardiac & Visceral Muscles of Thorax & Abdomen.
General & Special Visceral Afferent: Nucleus of Tractus Solitarius for Taste fibers, Heart, Lungs, Abdominal Viscera, Baro & Chemoreceptors
Somatic Afferent: Spinal nucleus of Trigeminal for Skin of Ext. Acoustic Meatus, Auricle, Mucous Membranes of Larynx & Pharynx.

INTRACRANIAL COURSE: In the intracranial course, the fibers run forwards and laterally through the reticular formation of medulla between the olivary nucleus and inferior cerebellar peduncle. It emerges as 8 to 10 rootlets from the medulla, and is attached to its posterolateral sulcus.

EXTRACRANIAL COURSE:



APPLIED ANATOMY: Various branches of the vagus nerve are affected due to lesions. *Recurrent Laryngeal Nerve Palsies* are most common due to malignant disease (25%) and surgical damage (20%) during operations of thyroid gland, neck, esophagus, heart and lung. Because of its longer course, lesions of left are more frequent than those of right. High lesions of the vagus nerve, which affect the pharyngeal and superior laryngeal branches, cause difficulty in swallowing as well as vocal cords defects.

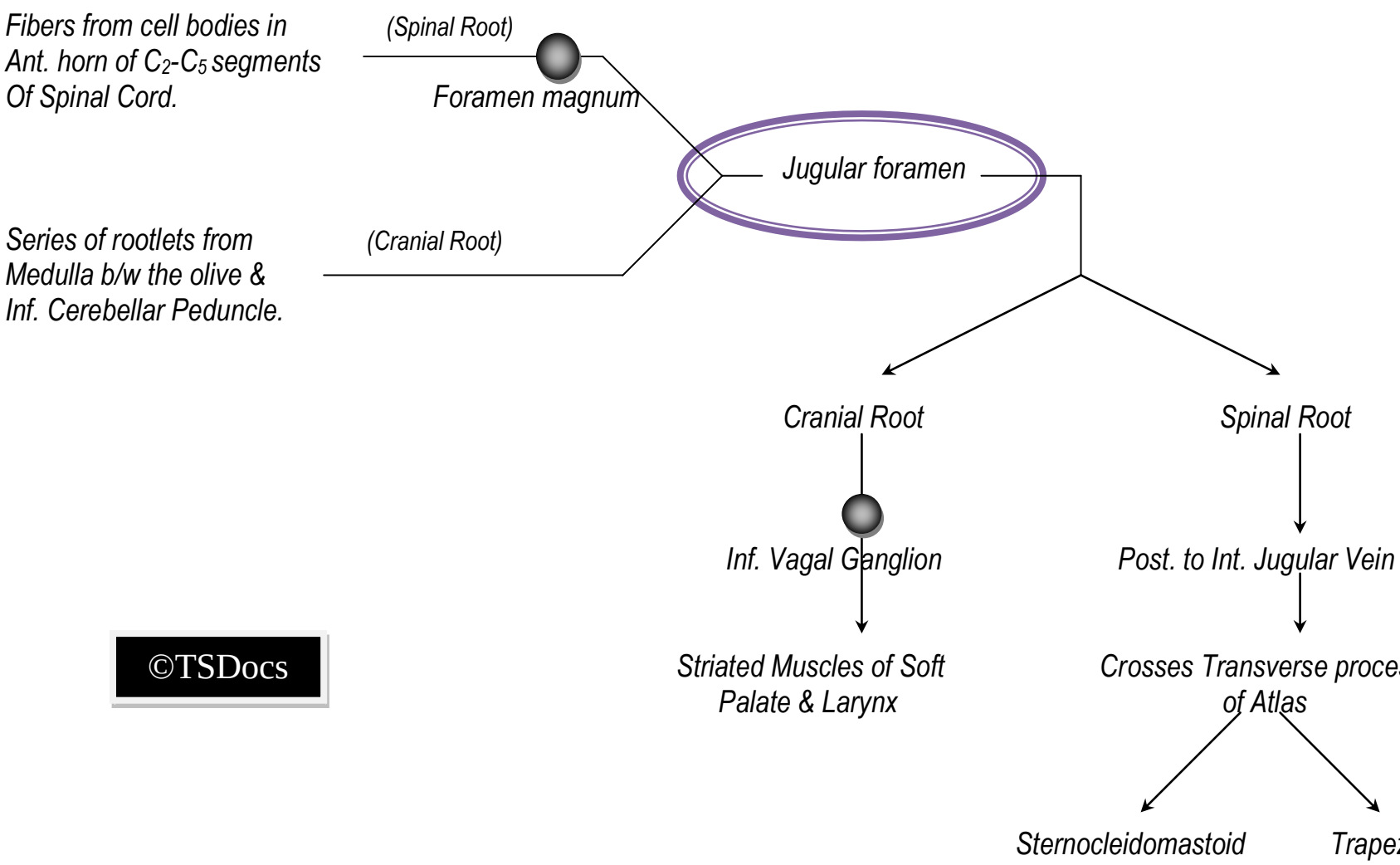
ACCESSORY NERVE:

The accessory nerve (CN-XI), is formed by the union of its spinal and cranial roots, but these are associated for a short distance only. The cranial part joins the vagus and is considered a part of it; it is a branchial or special visceral efferent nerve. The spinal root may be considered as somatic or special visceral efferent.

NUCLEI:

Branchial Efferent: Nucleus Ambiguus for cranial part- muscles of pharynx & palate.
Branchial Efferent: Ant. horn cells of upper 5 or 6 cervical segments for spinal part- sternocleidomastoid & trapezius.

COURSE AND PATHWAY:



APPLIED ANATOMY: Lesions of the spinal part of accessory nerve will result in paralysis of sternocleidomastoid and trapezius muscles. The sternocleidomastoid will atrophy and there will be weakness in turning the head to the opposite side. The trapezius muscle will also atrophy and the shoulder will droop on that side, there will also be weakness and difficulty in raising the arm above the horizontal. Lesions of the spinal part of the nerve may occur anywhere along its course and mostly results from the tumours or trauma from stab or gunshot wounds in the neck.

HYPOGLOSSAL NERVE:

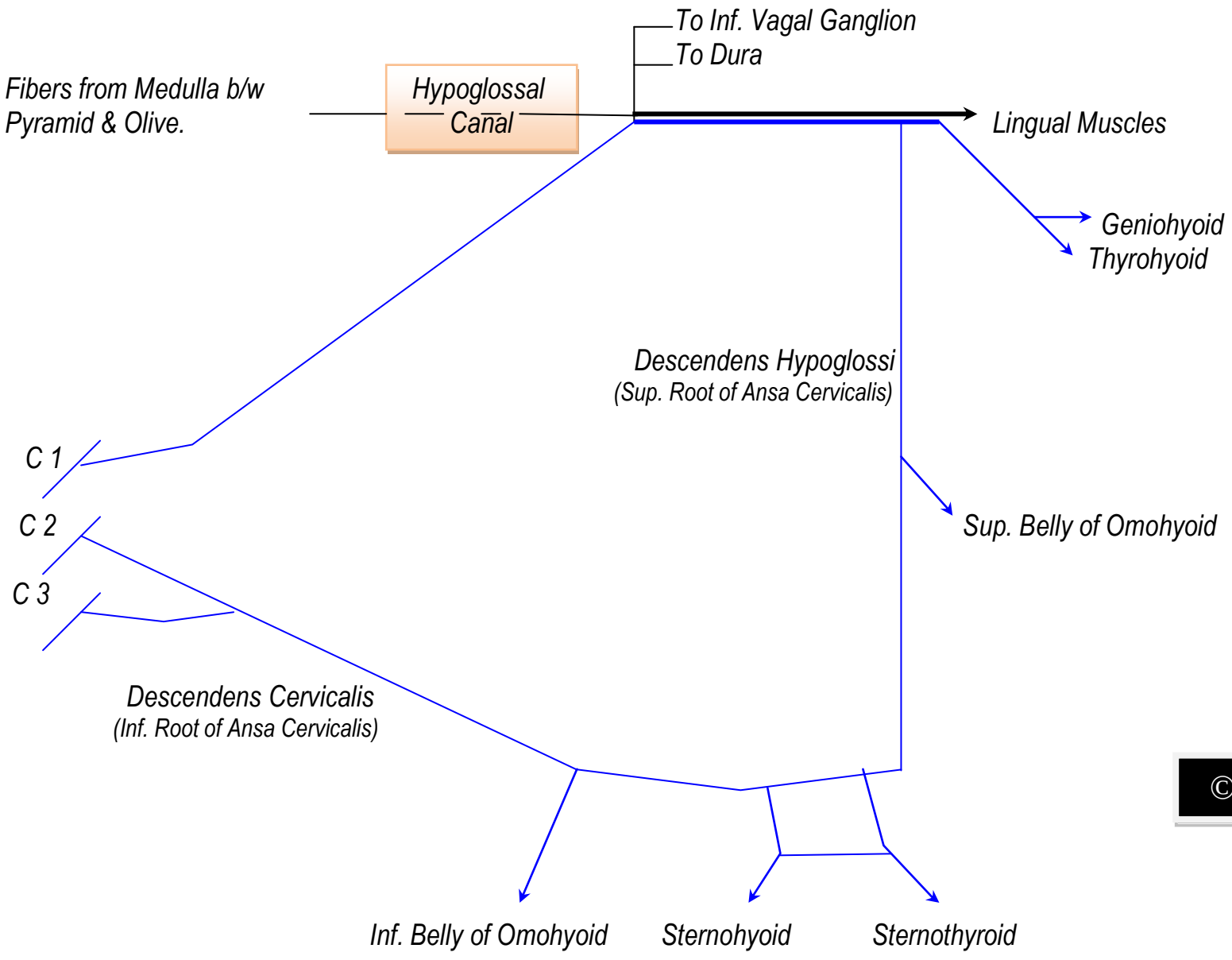
The hypoglossal nerve (CN-XII), is the main motor supply of tongue except the palatoglossus. It lies in line with the oculomotor, trochlear & abducent nerves and the ventral parts of the spinal nerves.

NUCLEUS:

Somatic Efferent: Hypoglossal nucleus in upper medulla for tongue.

INTRACRANIAL COURSE: In the intracranial course, fibers from the nucleus pass forwards lateral to the medial longitudinal bundle, medial leminiscus & pyramidal tract and medial to the reticular formation & olivary nucleus. The nerve is attached to the anterolateral sulcus of medulla, by 10 to 15 rootlets.

EXTRACRANIAL COURSE:



APPLIED ANATOMY: Complete hypoglossal nerve lesion causes unilateral lingual paralysis and hemiatrophy; the protruded tongue deviates to the paralysed side; on retraction, the wasted and paralysed side also rises higher than the unaffected side. The larynx may deviate towards the active side in swallowing due to unilateral paralysis of the hyoid depressors. Lesions of the hypoglossal nerve may occur anywhere along its course and may result from tumour, demyelinating diseases, syringomyelia and vascular accidents.

References:

Grey's Anatomy, Last's Anatomy, Snell's Clinical Neuroanatomy