CRANIAL NERVE NUCLEI, FUNCTIONAL COLUMNS/ COMPONENTS, AND THEIR DEVELOPMENT

Abstract

Neuroanatomy is a vast subject to study and knowledge of cranial nerves gives bounce points in the subject. In this chapter, there is a general introduction of all the cranial nerves with their names. After that there is discussion on the development of functional components of all the cranial nerves in the spinal cord and brainstem individually. The material was referred from the previous papers, books and journals. The knowledge of development is mandatory to understand the functions of each cranial nerve. Then the details of each cranial nerve with their functional component, location of nerve nuclei, their course and most important their clinical aspects are written in text and also in tabulated form for quick revision.

Keywords: Neuroanatomy, cranial nerve, Functional component, Palsy, Clinical aspect

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Cranial nerves are in pairs of 12. Except for I and II, the most of cranial nerves originate from the brainstem. They arise from forebrain. Some authors said, 1st and 2nd nerves are not true nerves. The names of cranial nerves shown in table 1.

Table 1: Names of Cranial Nerves

Cranial Nerve No:	**Name**
I	Olfactory N.
II	Optic N.
III	Oculomotor N.
IV	Trochlear N.
V	Trigeminal N.
VI	Abducent N.
VII	Facial N.
VIII	Vestibulocochlear N.
IX	Glossopharyngeal N.
X	Vagus N.
XI	Accessory N.
XII	Hypoglossal N.

Except for the trochlear nerve, which emerges from the dorsal side of the brainstem, all cranial nerves are derived from the ventral surface.

I. DEVELOPMENT OF FUNCTIONAL COLUMNS IN SPINAL CORD

In early stage, during the development of spinal cord, a single layered neural tube is formed which is lined by ependymal layer. After that the wall of tube is divided into three layers. The layers from outer to inner side are as shown in figure 1:

- Marginal layer
- Mantle layer
- Ependymal layer

In the ventral region of the neural tube, the mantle layer expands quickly. Due to which, the lumen of ventral part of neural tube become narrow and a line demarcated the narrow ventral part from the dorsal part. This line of demarcation is known as sulcus limitans. Due to the formation of sulcus limitans, the spinal cord divide into dorsal Alar plate/lamina and Ventral Basal plate/lamina.In both lamina all the layers are present (marginal, mantle, ependymal)

Figure 1: Showing the Development of Functional Column In The Spinal Cord

A. A single layer of neural tube
B. Three layered neural tube- Yellow (Marginal layer), Blue (Mantle layer), Green (Ependymal layer)
C. The dotted line represents the sulcus limitans, which separates the ventral basal lamina from the dorsal Alar lamina in the spinal cord's lateral wall.
D. Purple color shows alar lamina in gray matter (posterior horn), Pink color shows basal lamina (anterior horn).
E. Brown color – GSA column, Red color – GVA column, Blue color – GVE column, Orange color – GSE column

1. Alar Lamina/Plate

- The Cells Of Alar Lamina are Sensory i.e afferent.
- The posterior grey matter is made up of the nerve cells that are found in the mantle layer of this lamina.
- These second order nerve cells' axons travel upward in the alar lamina's marginal layer to create the spinal cord's ascending tracts, while the fibres from other sections of the brain move downward to create the descending tracts. The ascending and descending tracts thereby contribute to the formation of white matter.

2. Basal Lamina/Plate

- The basal lamina's cells are efferent motor cells by nature.
- The nerve cells present in the mantle layer of this lamina forms the anterior gray matter/horn/column.

3. Development of Functional Columns In Gray Matter of Spinal Cord

- In the gray matter of each plate two longitudinal functional columns of general sensations of visceral and somatic types are developed.
- General visceral components/columns are close to the sulcus limitans and General somatic components are far apart from sulcus limitans.
- Afferent columns in alar lamina- GSA & GVA
- Efferent columns in basal lamina- GVE & GSE

Therefore, total four functional columns/components are formed from **dorsal to ventral** aspect of spinal cord are:

1. GSA (General Somatic Afferent)
2. GVA (General Visceral Afferent)
3. GVE (General Visceral Efferent)
4. GSE (General Somatic Efferent)

Efferent- Exit (Away from brain)- Motor & Afferent – towards brain – sensory. Details given in table 2.

Table 2: **Functional Columns in Spinal Cord**

Components	**Functional column**	**Presence**	**Function**
Basal Lamina (MOTOR)	GSE	Throughout the spinal cord	Innervates Skeletal muscles
	GVE	Thoracolumbar & Sacral region	Provide preganglionic sympathetic fibers to supply smooth muscles of viscera, blood vessels, glands, and heart (Cardiac muscles)
Alar Lamina (SENSORY)	GVA	Thoracolumbar & Sacral region	Receive information from the viscera, blood vessels and glands.
	GSA	Throughout the spinal cord	Receives proprioceptive and exteroceptive information.

II. DEVELOPMENT OF FUNCTIONAL COLUMNS IN BRAINSTEM

In the brainstem, additional special(branchial) visceral functional columns are formed as shown in table 3 and 4. These functional columns developed between the General somatic and visceral components in both lamina (alar and basal). Then one additional special somatic afferent column is formed for hearing and equilibrium in alar lamina. So, functional columns of nuclei are arranged in seven columns instead of four as in spinal cord. The arrangement of these columns is from lateral to medial side is shown in figure2:

- SSA (Special Somatic Afferent)
- GSA (General Somatic Afferent)
- SVA (Special visceral afferent)
- GVA (General visceral afferent)
- GVE (General visceral efferent)
- SVE (Special visceral efferent)
- GSE (General Somatic efferent)

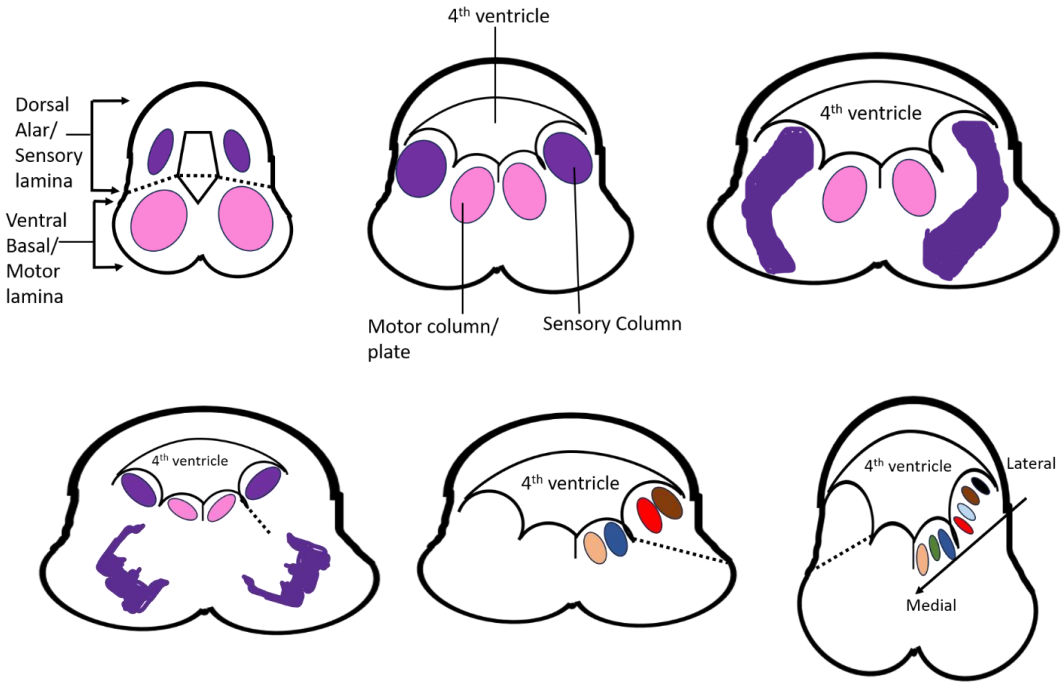

Figure 2: Showing The Development of Functional Column In The Brainstem(Medulla)

1. **SSA** (**Special Somatic Afferent Fibres)-** These fibres are concerned with the special sensations of **hearing and balance/equilibrium.** The cochlear apparatus and semicircular canals are responsible for auditory system(hearing) and vestibular system(balance) respectively developed from Otic placode. Otic placode is ectodermal in origin.

2. **GSA** (**General Somatic Afferent Fibres)-** These fibres transmit proprioceptive senses (vibration, muscle, and joint sense) as well as general sensations of pain, touch, and temperature from the skin.

3. **SVA (Special visceral afferent)-** It is a special component so it is concerned with the branchial development of taste buds of tongue (endoderm). So, these fibres carry special sensations of taste from the tongue.

4. **GVA (General visceral afferent)-** These fibres convey general sensations of ischemia, distension, and contraction from the upper GIT, heart, and lung with associated glands and blood arteries.

5. **GVE (General visceral efferent)-** These fibres nourish the blood vessels, visceral smooth muscles, and glands.

6. **SVE (Special visceral efferent)-** These fibres are special components to supply the skeletal muscles which are developed from the pharyngeal/branchial arches. Muscles of

mastication (1st arch), Muscles of facial expressions (2nd arch), Stylopharyngeus (3rd arch), Palatal, Pharyngeal, Laryngeal muscles (4th and 6th arch).

7. **GSE (General Somatic efferent)-** These fibres supply the skeletal muscles which developed from the somites. Muscles of limbs and body walls.

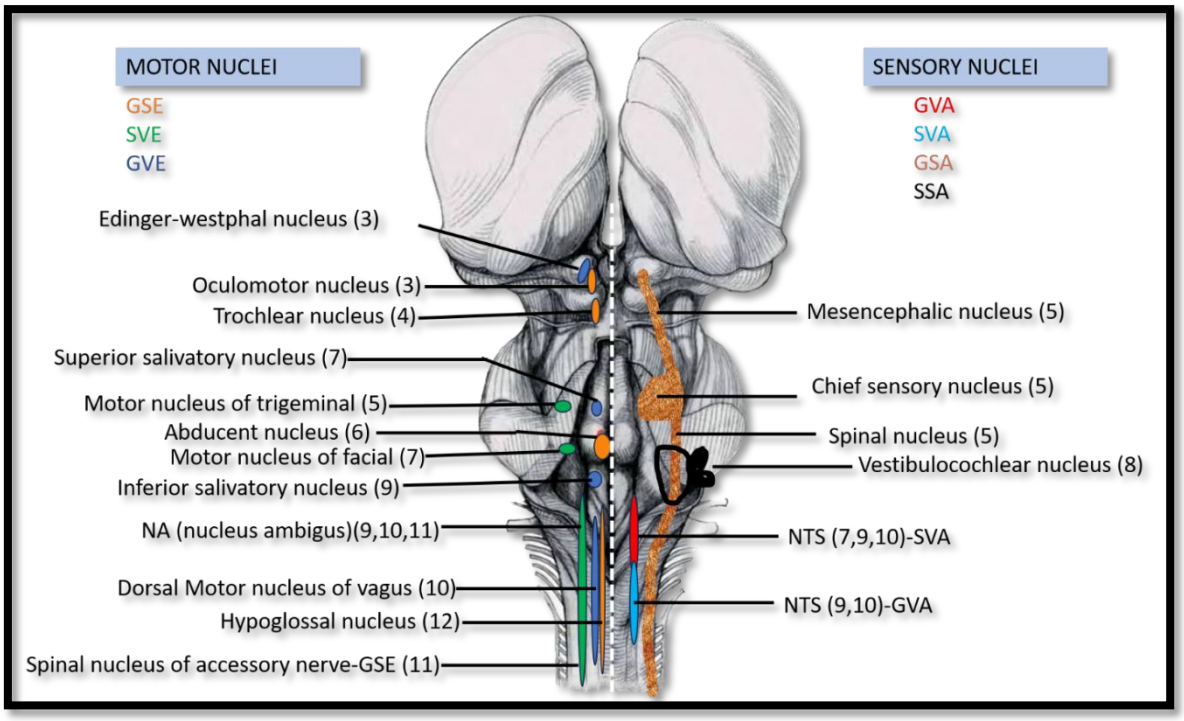

Table 3: Motor Functional Columns in Brain Stem

Components	Functional column	Cranial N. Nuclei	Location	Functions
Basal Lamina (MOTOR)	GSE	Oculomotor (3)	Upper Midbrain	Extraocular muscles of eyeball
		Trochlear (4)	Lower Midbrain	Superior oblique muscle of eyeball
		Abducent (6)	Lower pons	Lateral rectus muscle of eyeball
		Hypoglossal (12)	Medulla	Muscles of tongue except palatoglossus
	SVE	Motor nucleus of trigeminal (5)	Upper pons	Mastication muscles, mylohyoid & Ant belly of digastric, tensor tympani & tensor palati
		Facial Nerve nucleus (7)	Lower pons	Facial muscles, auricular muscles, muscles of scalp, stapedius, post belly of digastric and stylohyoid
		Nucleus	Medulla	Stylopharyngeus, Muscles of

		ambiguous (NA) (9,10,11)		larynx and pharynx, SCM and trapezius	
	GVE	Edinger-westphal nucleus (3)	Upper Midbrain	oculomotor N	Relay in ciliary ganglion and supply ciliaris and Sphincter pupillae.
		Superior Salivatory nucleus (7)	Ponto-medullary junction on dorsal aspect of pons.	Facial N	Relay in Submandibular ganglion & supply glands (Submandibular & sublingual).
		Inferior Salivatory nucleus (9)		Glossopharyngeal N	Relay in otic ganglion & supply parotid gland
		Lacrimatory nucleus (7)		Facial N	Relay in pterygopalantine ganglion & supply lacrimal gland
		Dorsal nucleus of vagus(10)	Medulla	Vagus N	Relay in ganglia and nerve plexuses around the viscera and then posganglionic fibres arise and supply the smooth muscles, glands of the organs (heart,

					bronchi, lungs, esophagus, stomach, SI & LI upto Rt. 2/3rd of transverse colon)

Table 4: Sensory Functional Columns in Brain Stem

Components	Functional column	Nuclei	Location	Functions
Alar Lamina (SENSORY)	GVA	NTS (Nucleus tractus solitarius)	Medulla	Receives general sensations of distension, contraction and ischemia from the upper part of GIT, heart and lung with their glands and blood vessels (Vagus N) and from pharynx (glossopharyngeal N)
	SVA	NTS (Nucleus tractus solitarius)	Medulla	Receives taste sensations from the tongue through facial, glossopharyngeal and vagus nerve.
	GSA – Consist three sensory nuclei of trigeminal nerve	Mesencephalic nucleus	Extend from main nucleus into midbrain	It is a centre for the jaw jerk
		Main Sensory nucleus	In upper part of pons	Mediates the touch, pressure, and proprioceptive impulses of face.
		Spinal nucleus	Extend from main nucleus into medulla	Mainly concerned with pain and thermal sensibility
	SSA	Vestbulocochlear nuclei	At level of ponto-medullary junction	Helps in maintenance of equilibrium and balance, hearing.

III. DETAIL OF FUNCTIONAL COLUMNS (COMPONENTS) WITH THEIR NUCLEI OF INDIVIDUAL CRANIAL NERVES

1. Olfactory Nerve

It is the first cranial nerve for smell.
This nerve classified under **SSA (**special somatic afferent) functional column because olfactory mucosa is developed from the ectoderm as otic placode for vestibulocochlear nerve.
Some authors consider under **SVA** (special visceral afferent) because of its relationship with the sense of smell and taste.

2. Optic Nerve

It is not a true nerve rather it is a tract.
It contains **SSA (**special somatic afferents) for vision.

3. Occulomotor Nerve: Functional components: It contains GSE and GVE

- **GSE:** All of the extrinsic eyeball muscles, with the exception of the Lateral Rectus(LR)and Superior Oblique(SO), are supplied by these fibres, which originate in the occulomotor nucleus (3).
  LR is supplied by Abducent nerve and SO is supplied by Trochlear nerve.
  Point - (LR 6 SO 4- other by 3) - For muscles of eyeball

- **GVE:** As far as the peripheral nervous system is concerned, these fibres are involved. The midbrain's Edignger-Westphal nucleus is where the preganglionic fibres originate, and they lead to the ciliary ganglion. After that, post-ganglionic fibres form in the ganglion and supply the ciliaris and sphincter pupillae muscles, which aid in accommodating the lens and constricting the pupil, respectively.

4. Trochlear Nerve : Functional components:

- **GSE-** The SO (Superior oblique) muscle of the eyeball is supplied by GSE fibres that originate in the trochlear nucleus.

5. Trigeminal Nerve: Functional components: It contains SVE and GSA fibres.

- SVE: Muscles for mastication, the anterior belly of the diagastric, mylohyoid, tensor tympani, and tensor palati are supplied by fibres that emerge from the **motor nucleus** of trigeminal nerve. These muscles are derivatives of first pharyngeal arch.

- **GSA:** Fibres are divided into two groups:-The mucous membranes of the mouth and nose, as well as the skin of the face, transmit exteroceptive sensations via fibres. The trigeminal nerve's sensory root is made up of the central processes of neurons in the ganglion, which terminate in the ascending and descending branches of the **primary sensory nucleus** and **spinal nucleus**, respectively.

-Another set of fibres that transmit proprioceptive signals from the tongue, teeth, and temporomandibular joint as well as the mastication muscles. These neurons' cell bodies are located in the **mesencephalic nucleus**.

6. Abducent Nerve

Functional Components: The lateral rectus muscle of the eye is exclusively supplied by **GSE** fibres, which only emerge from the abducent nucleus.

7. Facial Nerve : Functional components: It contains SVE, GVE, SVA, GSA

- **SVE:** These fibres arise from the **motor nucleus of facial nerve** and supply the facial muscles which are mainly derivatives of 2^{nd} pharyngeal arch.

- **GVE:** Preganglionic parasympathetic fibres from the lacrimatory and superior salivatory nuclei relay in the pterygopalatine and submandibular ganglions, respectively, and postganglionic fibres emerge from these ganglions to supply the lacrimal and submandibular glands with the sublingual gland, respectively.

- **SVA:** These fibres are responsible for taste perception, and their cell bodies are located in the geniculate ganglion. With the exception of the vallate papillae, taste sensations are transmitted from the taste buds on the front two-thirds of the tongue by the peripheral processes of ganglion cells. These sensations are transmitted to the upper region of NTS through the central processes of ganglion cells.

- **GSA:** The cell bodies of these fibres lies in the geniculate ganglion and the peripheral processes of these cells innervates the external ear and the central processes ends in the spinal nucleus of trigeminal nerve.

8. Vestibulocochlear Nerve

Functional Components: This nerve consists of two divisions: cochlear and vestibular. Both these divisions consist of **SSA fibres**.

The spiral ganglion's **bipolar neurons** give rise to the **cochlear nerve's fibres**. The 'organ of Corti' (hearing receptor) in the cochlea of the inner ear is innervated by these cells' peripheral processes.

The bipolar neurons in the vestibular ganglion's central processes are the fibres of the **vestibular nerve.** For kinetic and static balance, respectively, the vestibular receptors in the semicircular ducts, saccule, and utricle of the inner ear are innervated by these Neurons' Peripheral Processes.

9. Glossopharyngeal Nerve

Functional Components:

- **SVE Fibres:** Comes from the nucleus ambiguus and supplies the stylopharyngeus, a single muscle.

- **GVE Fibres:** begin in the otic ganglion and relay in the inferior salivatory nucleus. Postganglionic fibres then supply the parotid gland through the auriculotemporal nerve.

- **GVA Fibres**: These fibres travel to the ganglion from the carotid body, carotid sinus, carotid body posterior third of the tongue, and carry general touch, pain, and temperature sensations. The trigeminal nerve's spinal nucleus receives these sensations from the central processes.

- **SVA Fibres**: The Cell bodies are located in the glossopharyngeal nerve's inferior ganglia. These cells' peripheral processes transport taste impressions from the back portion of the tongue around the papillae to the ganglion. These impulses are sent to the NTS by the central processes.

10. Vagus Nerve

Functional Components:

- **SVE Fibres:** The pharynx and larynx muscles are supplied by SVE fibres, which emerge from the nucleus ambiguus.

- **GVE Fibres:** which come from the dorsal nucleus of the vagus—supply the heart, lungs, and GIT all the way to the intersection of the right and left thirds of the transverse colon.

- **GVA Fibres**: These fibres' cell bodies' peripheral processes send sensations from the pharynx, larynx, trachea, oesophagus, and thoracic and abdominal viscera to the ganglion, from where they are sent through central processes to the dorsal nucleus of the vagus and NTS.

- **SVA Fibres**: These fibres carry taste signals from the back of the tongue and the epiglottis to the ganglion, where they come to an end in the upper portion of the NTS.

- **GSA Fibres:** These fibres supply the external ear's skin and come to an end at the trigeminal nerve's spinal nucleus.

11. Accessory Nerve

Functional Components:
This nerve contains SVE (Cranial Root) and GSE (Spinal Root) functional columns.

- **SVE Fibres:** All the laryngeal muscles, all the muscles of the palate, save for the tensor palati (nerve to the medial pterygoid), and all the muscles of the pharynx, except for the stylopharyngeus (IX nerve), receive special visceral efferent fibres from the nucleus ambiguus.

- **GSE Fibres:** Arise from spinal nucleus of accessory nerve. These fibres supply trapezius and sternocleidomastoid muscles.

12. Hypoglossal Nerve

Functional Components:

- **GSE Fibres**: Arise from hypoglossal nucleus and supplies all the tongue's intrinsic and extrinsic muscles, excluding the palatoglossus(Vago-Acessory complex) .

Table 5: Brief of Cranial Nerve Nuclei with Functional Columns and Functions

Cranial nerve	Functional column	Nuclei	Course	Area supplied	Functions	Clinical Anatomy
I (Olfactory N)	SSA/SVA	Olfactory[#] epithelium (receptor cells)	Pass through cribriform plate	Olfactory epithelium	Smell	Loss of smell
II (Optic N)	SSA	Bipolar cells of Retina	Comes out through optic canal and form optic chiasma	Supply retina of eye	Nerve of vision.	Blindness (Hemianopia)
III (Oculomotor N)	GSE	Oculomotor nucleus	Enter orbit through superior orbital fissure and divide into superior and inferior division	Supply the extraocular muscles (Superior, medial and inferior recti, Inferior oblique and LPS muscles)	Eyeball movement and Accomodation reflex	Lateral squint and strabismus
	GVE	Edinger-westphal nucleus	Fibres relay in ciliary ganglion then through short ciliary nerves postganglionic fibres supply the muscles.	supply the sphincter pupillae and ciliaris muscle.		
IV (Trochlear N)	GSE	Trochlear nucleus	Enter orbit through superior orbital fissure	Supply superior oblique muscle of eyeball	Movement of eyeball	Trochlear nerve palsy- eye is extorted and

						elevated. Vertical diplopia occurs
V (Trigeminal N)	SVE	Motor nucleus	3 divisions: opthalamic, maxillary and mandibular. these nerves pass through superior orbital fissure (orbit), foramen rotandum, foramen ovale respectively.	Opthalamic nerve supply orbital structures, nasal cavity, skin of forehead, eyebrows, Maxillary nerve supply lower eyelid, upper lip, gums, palate and part of pharynx. Mandibular nerve supply lower gums, teeth, part of palate and tongue(sensory) and motor to muscles of mastication	Movement of mandible General sensations of face (touch,pain and temperature) Proprioceptive sensations	Trigeminal neuralgia- sudden onset of pain in the face (cutaneous supply) Lesion- hypoacusis, loss of general sensations, paralysis of muscles of mastication
	GSA	Mesencephalic, main sensory and spinal nucleus				
VI (Abducent N)	GSE	Abducent nucleus	Enter orbit through superior orbital fissure	Lateral rectus muscle of eyeball	Abduction of eyeball	Medial /convergent squint or strabismus
VII (Facial N)	SVE	Motor nucleus	Enter the internal acoustic meatus and enter to middle ear cavity then become extracranial through stylomastoid foramen and	Motor supply facial muscles, salivary glands, glands of soft palate. Taste sensation from ant 2/3rd of tongue via chorda tympani branch	Facial expression, Taste sensations, exteroceptive sensations of external ear	Upper motor neuron lesion (UML) and Lower motor neuron lesion (LMN). Bell’s palsy (infranuclear/LMN palsy)
	GVE	Superior salivatory nucleus				
	SVA	NTS				
	GSA	Spinal nucleus o trigeminal				

			enter into parotid gland and divide into five branches to supply the facial muscles.			
VIII (Vestibulo-cochlear N)	SSA	Vestibular and cochlear nucleus	Enter the internal acoustic meatus and enter to middle ear cavity and become cochlear and vestibular divisions	Cochlea and vestibule	Hearing and balance	Deafness, vertigo, nystagmus, loss of balance and equilibrium.
IX (Glossopharyngeal N)	SVE	NA	Pass through jugular foramen and comes in the neck	Supply stylopharyngeus muscle and parotid gland (MOTOR) Sensory for posterior 1/3rd of tongue	General sensations of touch, pain and temperature from pharynx and taste sensation from posterior 1/3rd of tongue & vallate papillae Secretomotor (parotid gland)	Lesion- lost of all the actions Loss of carotid sinus and gag reflex.
	GVE	Inferior salivatory nucleus				
	GVA	NTS				
	SVA	NTS				
	GSA	Spinal nucleus of trigeminal				
X (Vagus N)	SVE	NA	Exit through jugular foramen,	Supply dura mater of posterior cranial fossa,	Taste sensation from	Lesion- loss of gag and carotid sinus
	GVE	Dorsal				

		vagus nucleus	enter into the carotid sheath in neck, in thorax and then pass through the diaphragm and enter into abdominal cavity and this nerve form the plexuses around the organs.	carotid sinus and body, exterior tympanic membrane, external auditory meatus and surface of auricle Taste sensation from posteriomost part of tongue General Sensations from larynx,phrynx,trachea,oesophagus, thoracic and abdominal viscera.	posteriomost part of tongue. General sensation from viscera Motor and secretomotor to bronchial tree and gut	reflex. Hoarsness of voice.
	GVA	NTS				
	SVA	NTS				
	GSA	Spinal nucleus of trigeminal				
XI (Accessory N)	SVE	Accessory nucleus	Formed by 2 roots.cranial and spinal Pass through the jugular foramen	Supply through vagoacessory complex to muscles of pharynx, larynx and palate. Sternocleidomastoid and trapezius	Movement of palate,pharynx and larynx Movement of head and shoulder.	Lesion- paralysis of SCM and trapezius. Drooping of shoulder. Wry neck
XII (Hypoglossal N)	GSE	Hypoglossal nucleus	Pass through hypoglossal canal and comes in the neck superficial to external carotid and reach above the hyoid bone to supply muscles of tongue.	Muscles of tongue except palatoglossus.	Movement of tongue	UML -tongue deviate to opposite side of lesion on protusion. LML- Tongue deviates to the same side of lesion.