CHAPTER 20

Functional Components of Spinal and Cranial Nerve Nuclei

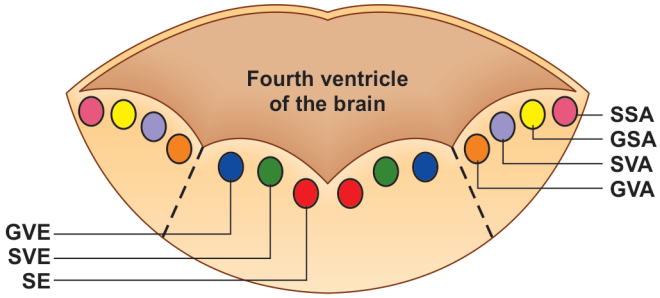
A **cranial nerve nucleus** is a collection of neurons (grey matter) in the brainstem that is associated with one or more cranial nerves. Axons carrying information to and from the cranial nerves form a synapse first at these nuclei. Lesions occurring at these nuclei can lead to effects resembling those seen by the severing of nerve(s) they are associated with. All the nuclei except that of the trochlear nerve (CN IV) supply nerves of the same side of the body.

STRUCTURE OF CRANIAL NERVE NUCLEUS

Motor and Sensory

In general, motor nuclei are closer to the front (ventral), and sensory nuclei and neurons are closer to the back (dorsal). This arrangement mirrors the arrangement of tracts in the spinal cord.

- Close to the midline are the **motor efferent nuclei**, such as the oculomotor nucleus, which control skeletal muscle. Just lateral to this are the **autonomic (or visceral) efferent nuclei.**
- There is a separation, called the sulcus limitans, and lateral to this are the **sensory nuclei**. Near the sulcus limitans are the **visceral afferent nuclei**, namely the solitary tract nucleus.
- More lateral, but also less posterior, are the **general somatic afferent nuclei.** This is the trigeminal nucleus. Back at the dorsal surface of the brainstem, and more lateral are the **special somatic afferents**, this handles sensation such as balance.



Functional group of cranial nerves:

I. Olfactory nerve: **Sensory**
II. Optic nerve: **Sensory**
III. Oculomotor nerve: **Motor**
IV. Trochlear nerve: **Motor**
V. Trigeminal nerve: **Mixed** (sensory+motor)
VI. Abducent nerve: **Motor**
VII. Facial nerve: **Mixed**
VIII. Vestibulocochlear nerve: **Sensory**
IX. Glossopharyngeal nerve: **Mixed**
X. Vagus nerve: **Mixed**
XI. Accessory nerve: **Motor**
XII. Hypoglossal nerve: **Motor**

AFFERENTS

SSA Cochlear and vestibular nuclei
GSA Sensory nuclei of trigeminal nerve
SVA Taste–rostral solitary nucleus
GVA Taste–rostral solitary nucleus

Sulcus limitans

EFFERENTS

GVE **Parasympathetic nuclei:**
Edinger-Westphal nucleus
Lacrimal, salivatory (superior and inferior)
Dorsal motor nucleus of X cranial nerve

SVE Motor nuclei of V, VII, IX and XI nerves
SE Motor nuclei of III, IV, VI, and XII nerves

Fig. 20.1: Functional groups of cranial nerves listed on the left columns are shown on the right

- Another area, not on the dorsum of the brainstem, is where the **special visceral efferents nuclei** reside. These formed from the pharyngeal arches, in the embryo. This area is a bit below the **autonomic motor nuclei**, and includes the nucleus ambiguus, facial nerve nucleus, as well as the motor part of the trigeminal nerve nucleus (Fig. 20.1).

FUNCTIONAL COMPONENTS OF NERVES

As stated above the nerves arise either from the spinal cord–spinal nerves; or from the brain–cranial nerves. The spinal and cranial nerves both contain *three* kinds of fibers: (i) sensory (*afferent*), (ii) motor (*efferent*), and (iii) a combination of sensory and motor (*mixed*) fibres. All these three kinds of fibres are classified on the basis of their embryological origin or common structural and functional characteristics.

Primary sensory fibers, somatic motor neurons, and pre- and post-ganglionic visceromotor neurons that exhibit, 'like anatomical and physiological characters so that they....act in a common mode' are classified as having a **specific functional component**. For example, fibres conveying sharp pain from widely separated body parts (the foot, hand, and face) have the same functional component is directly applicable to cranial nerves.

Development of Functional Components

In earlier stage of development, the neural tube is oval in outline with a narrow slit-like lumen. Later, the lateral walls of the neural tube (in the caudal portion to form the future spinal cord) thicken due to proliferation of the ependymal cells; the lumen widens in its dorsal part.

Functional Components in Spinal Nerves

A longitudinal groove called **sulcus limitans** develops on the inner aspect of the tube wall on each side. As a result, each lateral wall of the developing neural tube subdivides into a **dorsal** or **alar lamina** and a **ventral** or **basal lamina** (Fig. 20.2A).

Functional Components in Cranial Nerves

A sulcus limitans also develops in the rostral neural tube (the future brainstem—from where the true cranial nerves III–XII arise. The I and II cranial nerves being extension of the brain—hence not actual nerves). But the differentiation of the lateral walls of the neural tube into alar and basal laminae in the region of the developing hindbrain becomes different from that in the spinal cord (Fig. 20.2B). The dorsal edge of the alar lamina gives attachment to the thin expanded roof-plate and is termed the *rhombic lip*.

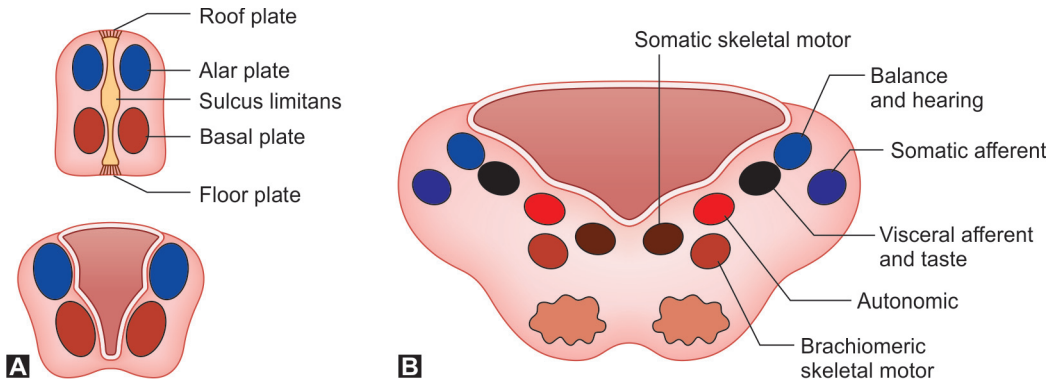
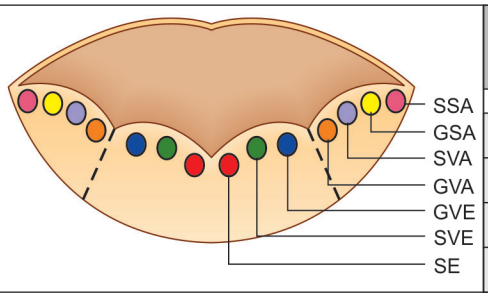


Fig. 20.2: Development of functional columns in: **A.** spinal nerves, and **B.** cranial nerves arising from brainstem

Purely Sensory Cranial Nerves [I, II, and VIII] (Fig. 20.3)



Nerves	AFFERENT COLUMNS				EFFERENT COLUMNS		
	SSA	GSA	SVA	GVA	GVE	SVE	SE
I	☹	☹		☹	☹	☹	☹
II		☹	☹	☹	☹	☹	☹
VIII–C		☹	☹	☹	☹	☹	☹
VIII–V		☹	☹	☹	☹	☹	☹

Notes:

i. The cranial nerves **I** and **II** both are not attached to brainstem; whereas the first or olfactory carries smell sensations from uppermost olfactory portion of the nasal cavity; the second nerve is regarded as outgrowth from the cerebral hemisphere being actually a collection of axons from the ganglion cells of the retina of the eye

ii. **VIII–C** = the cochlear division of VIII cranial carrying sensations from the cochlea of the internal ear

iii. **VIII–V** = the vestibular division of VIII cranial carrying sensations from the vestibule of internal ear. For the dual components, the VIII cranial nerve is termed vestibulocochlear (commonly named incorrectly only auditory) nerve

The **vestibulocochlear nerve** (auditory **vestibular nerve**), known as the **eighth cranial nerve**, transmits sound and equilibrium (balance) information from the inner ear to the brain.

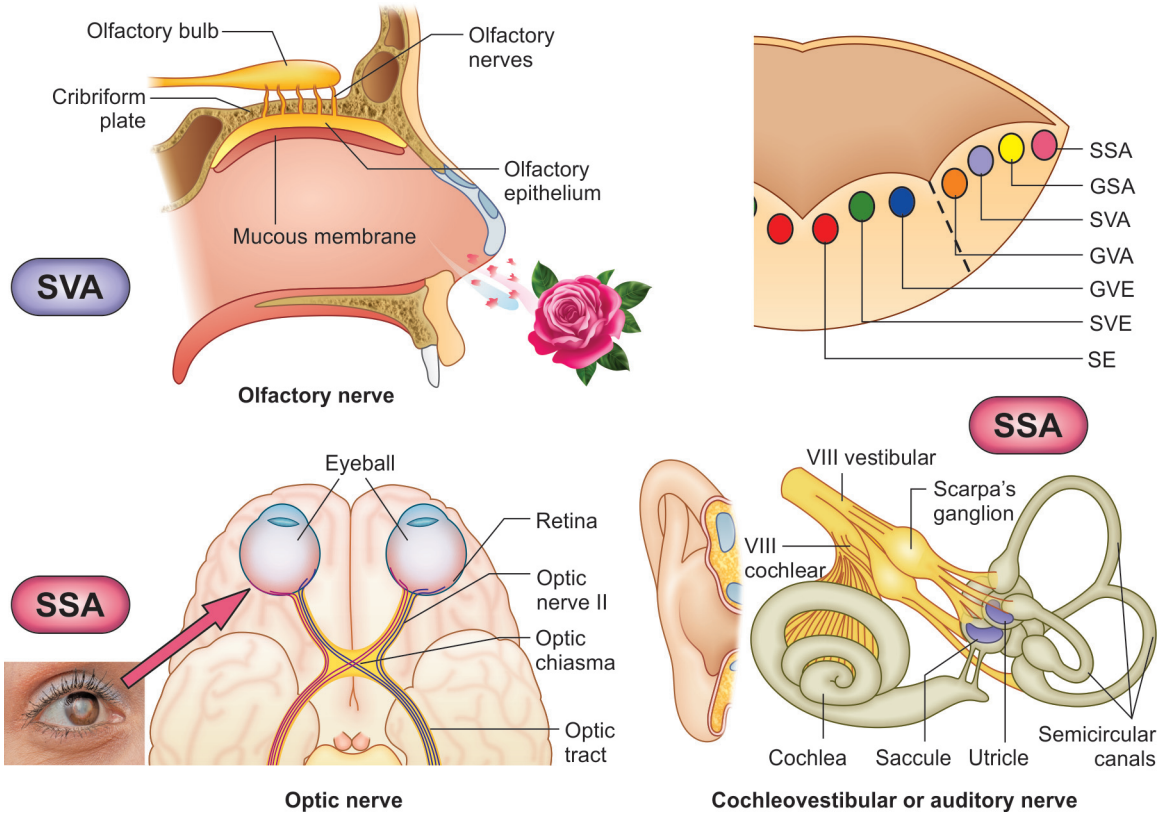
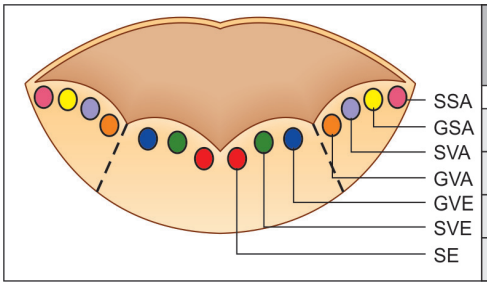


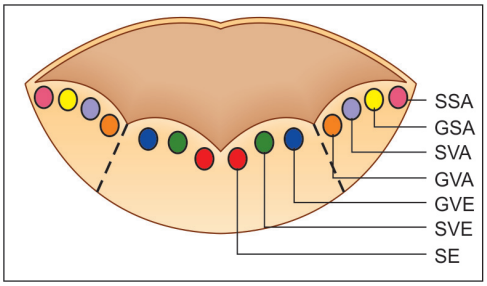
Fig. 20.3: Functional components in purely sensory nerves: I cranial (SVA: special visceral afferent); II cranial (SSA: special somatic afferent); and VIII cranial (SSA: special somatic afferent)

Primarily Motor Cranial Nerves [III, IV, VI, and XII] (Figs 20.4 and 20.5)



Nerves	AFFERENT COLUMNS				EFFERENT COLUMNS		
	SSA	GSA	SVA	GVA	GVE	SVE	SE
III	☹	☹		☹		☹	
IV	☹	☹	☹	☹	☹	☹	
VI	☹	☹	☹	☹	☹	☹	
XII	☹	☹	☹	☹	☹	☹	

Purely Motor Nerves [III, IV, VI and XII] have only Efferent Column(s)



EFFERENT COLUMNS		
GVE	SVE	SE
☹	☹	☹
☹	☹	☹
☹	☹	☹
☹	☹	☹

Notes:

i. All of the four cranial nerves in this category supply skeletal muscles NOT derived from the branchial arch mesoderm. Hence, these are named as somatic efferent (motor) nerves.

ii. The III cranial, the oculomotor, nerve emerges on the medial aspect of the crus cerebri; and is the only nerve out of the four listed in the somatic motor category, which consists of a GVE (general visceral efferent) component from Edinger-Westphal nucleus located in the periaqueductal grey matter and sends preganglionic parasympathetic fibres along the motor branch to the inferior oblique extraocular muscle—as the parasympathetic root of the ciliary (or ophthalmic) ganglion for the motor supply to the constrictor papillae muscle.

iii. The III cranial nerve supplies 5 out of 7 extraocular muscles (2 from the upper division—to the superior rectus and levator palpebrae superioris, and 3 from the lower division of the nerve for the supply of medial and inferior recti and inferior oblique muscle. Thus only 2 extraocular muscles (lateral rectus and superior oblique are not innervated by the third cranial.

iv. Palsy of the nerve to the muscle levator palpebrae (usually congenital) is a major cause of drooping of the upper eyelid resulting into a clinical entity called **ptosis**

v. The IV cranial nerve called trochlear is the only cranial nerve that emerges on the dorsal aspect of the brainstem at the level of the inferior colliculus of the midbrain, encircles the crus cerebri to reach on the ventral aspect, finally supplying only one extraocular muscle—the superior oblique.

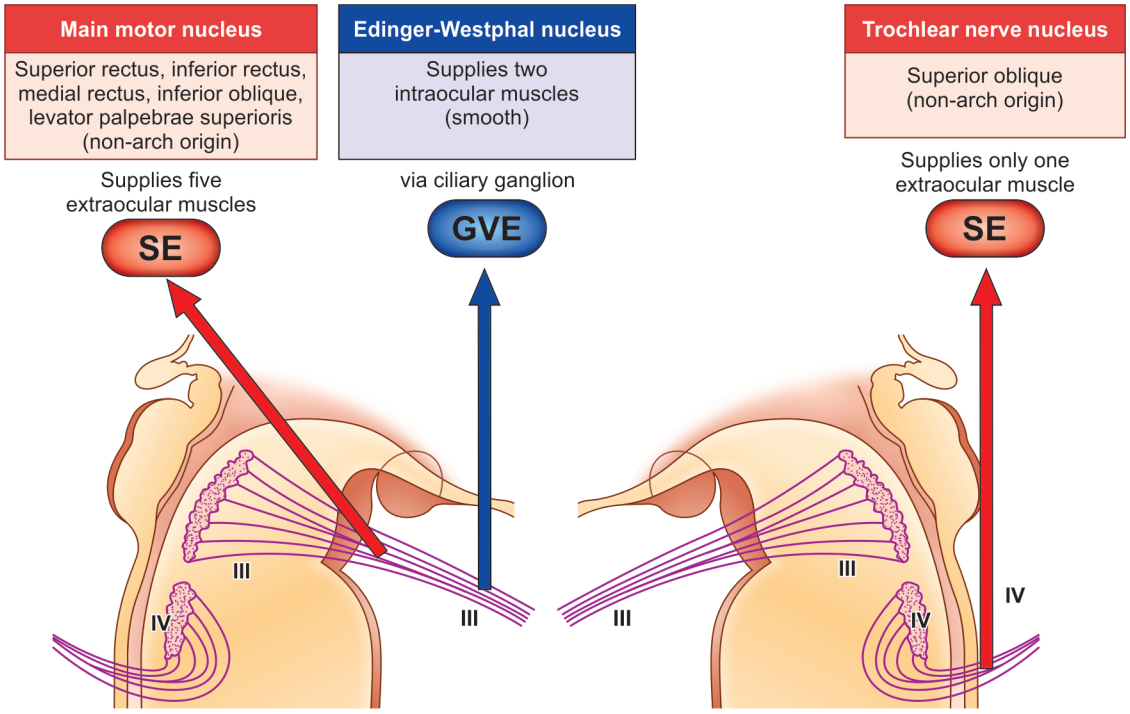


Fig. 20.4: Functional component [SE] of III cranial (oculomotor) and IV cranial (trochlear) nerves

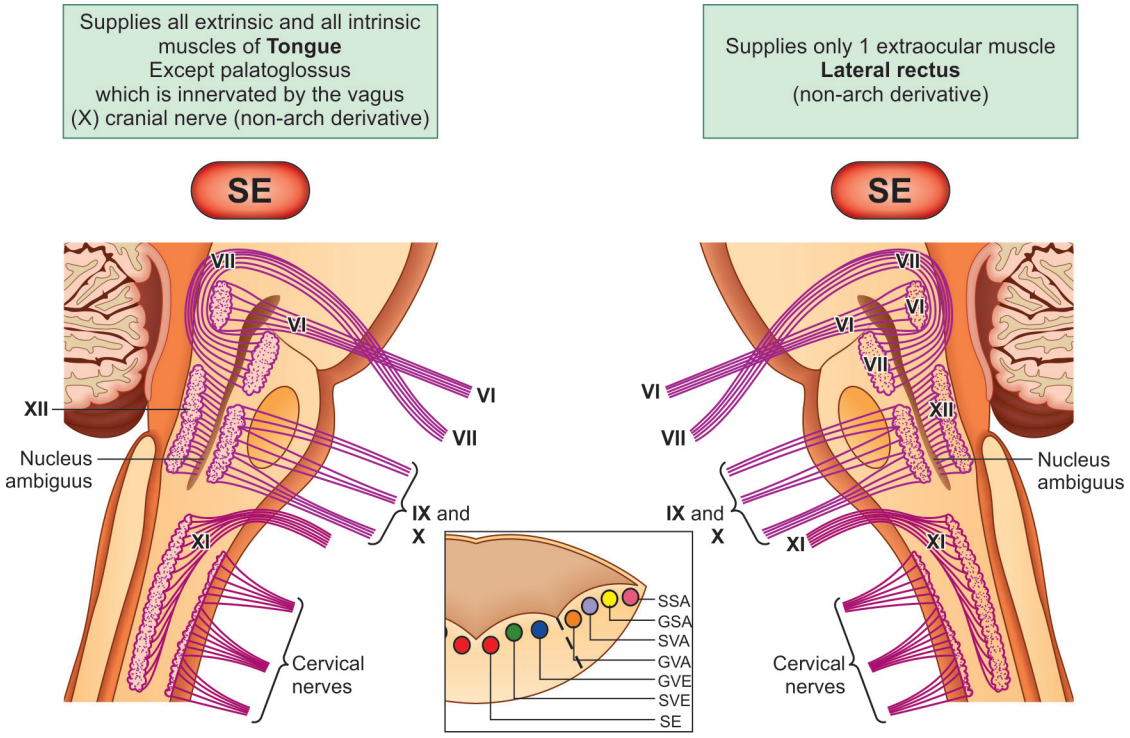


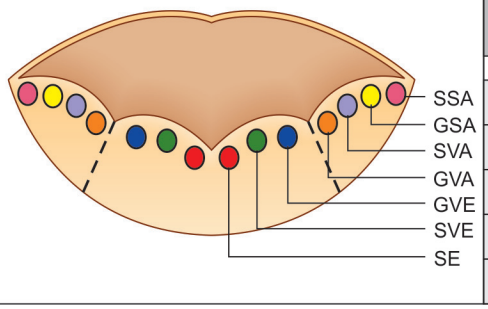
Fig. 20.5: Functional component of VI cranial (abducens) and XII cranial (hypoglossal) nerve is same and in each nerve only one–somatic efferent (SE) column

Mixed Cranial Nerves (both sensory and motor functions) V, VII, IX, X, and XI Spinal
(Figs 20.6 to 20.10)

Notes:

i. The V cranial nerve (trigeminal) consists of 4 nuclei, out of which 3 are **sensory nuclei** named from rostral to caudal side these are: (a) *mesencephalic nucleus of V*, (b) *main* (or *superior*) *sensory nucleus of V*, and (c) n*ucleus of spinal tract of V;* and 1 is a **motor nucleus**

Mixed Cranial Nerves (V, VII, IX, X and XI) have both Afferent and Efferent Column(s)



Nerves	AFFERENT COLUMNS				EFFERENT COLUMNS		
	SSA	GSA	SVA	GVA	GVE	SVE	SE
V	☹		☹	☹	☹		☹
VII	☹			☹			☹
IX	☹						☹
X	☹						☹
XI (sp)	☹	☹	☹	☹	☹	?	

☹ The face sign signifies—absent

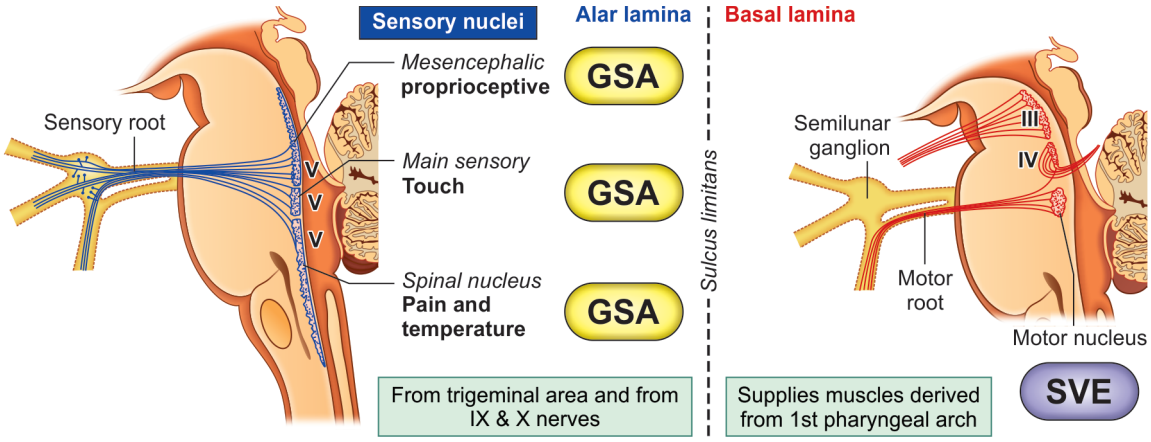


Fig. 20.6: Functional components of V cranial (trigeminal) nerve are both from the alar and basal laminae, because the mandibular division carries fibres for the muscles derived from the 1st pharyngeal arch. The ophthalmic and maxillary divisions are pure sensory. Notice different kinds of sensations are related with the different sensory nuclei described in the text

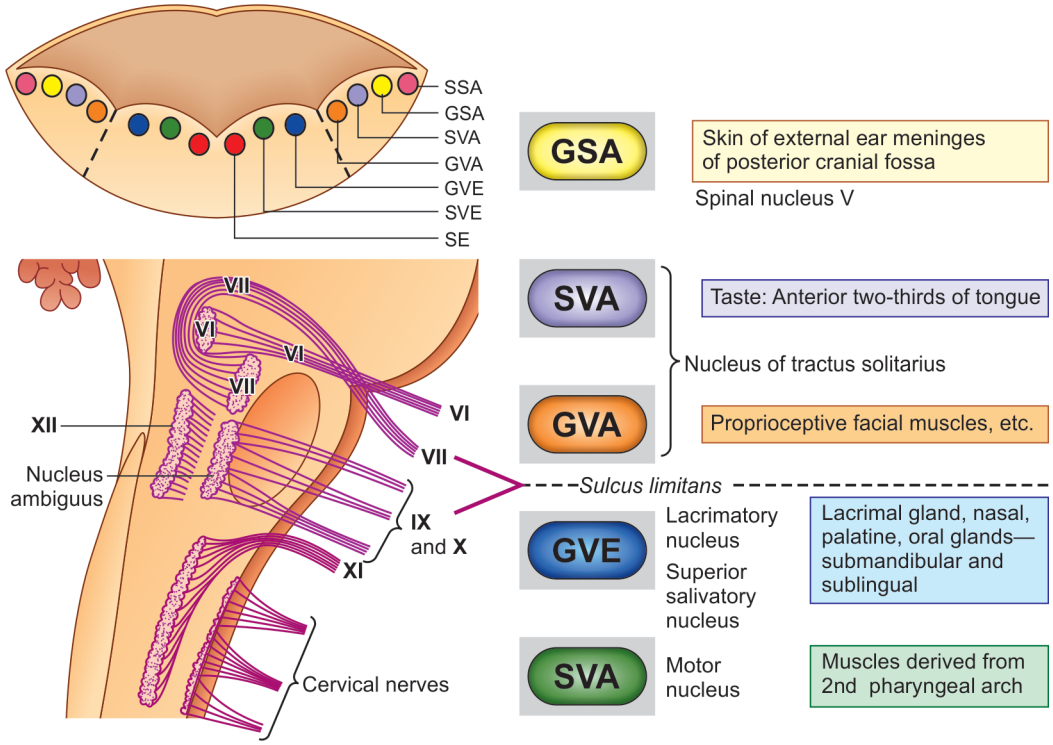


Fig. 20.7: Functional components of VII cranial (facial) nerve are both from the alar (SVA, GVA, and GSA) and basal (GVE and SVE) laminae. The figure details nuclei involved for sensations and supply to muscle and glands of salivary, nasal, and palate and oral region

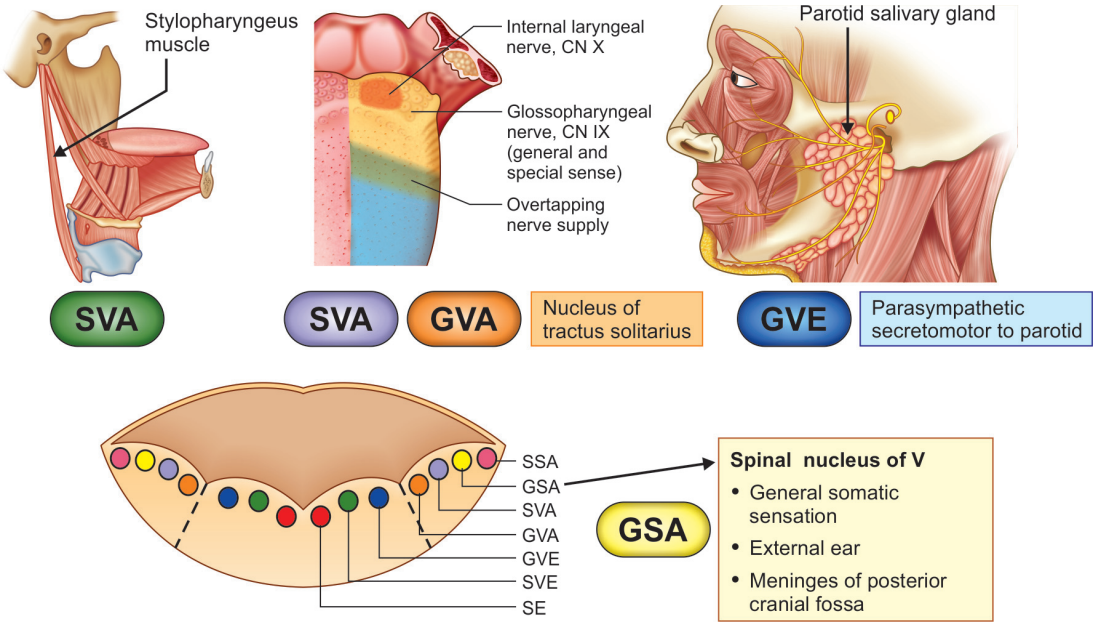


Fig. 20.8: Functional components of IX cranial (glossopharyngeal) nerve also are both from the alar (SVA, GVA, and GSA) and basal (GVE and SVE) laminae. The IX cranial nerve is the nerve of the 3rd pharyngeal arch and supplies the only muscle—stylopharyngeus derived from this arch

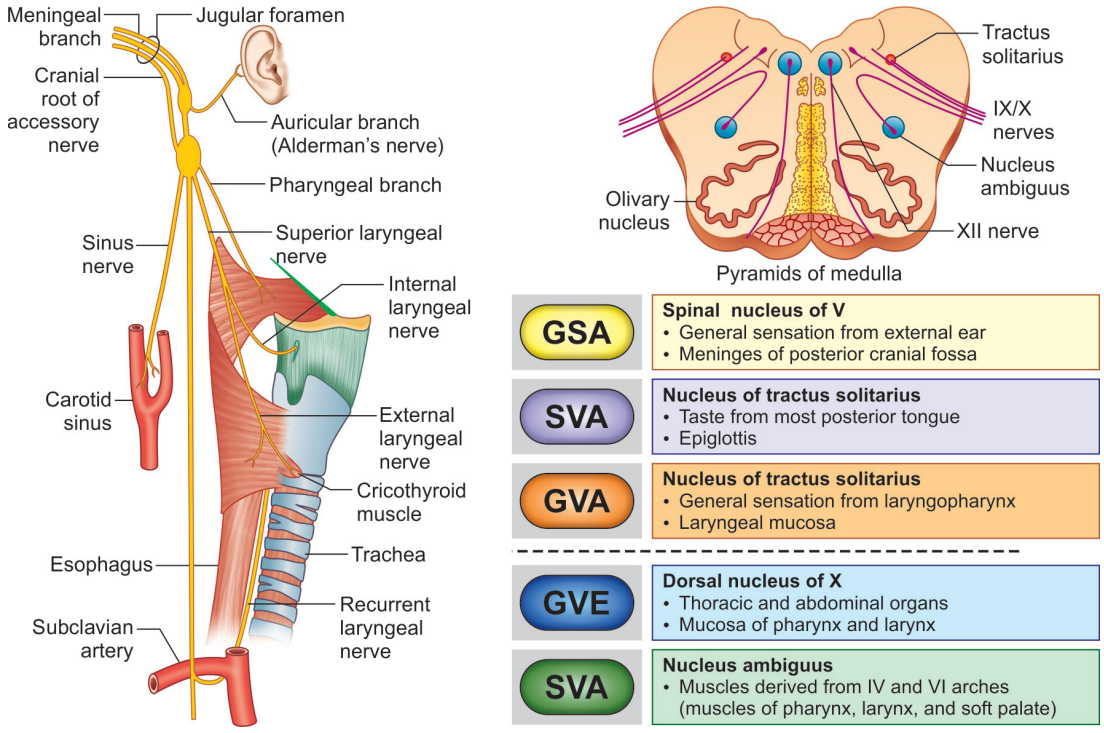


Fig. 20.9: Functional components of X cranial (vagus) nerve also are both from the alar (SVA, GVA, and GSA) and basal (GVE and SVE) laminae. These are similar to the five components of the IX cranial nerve

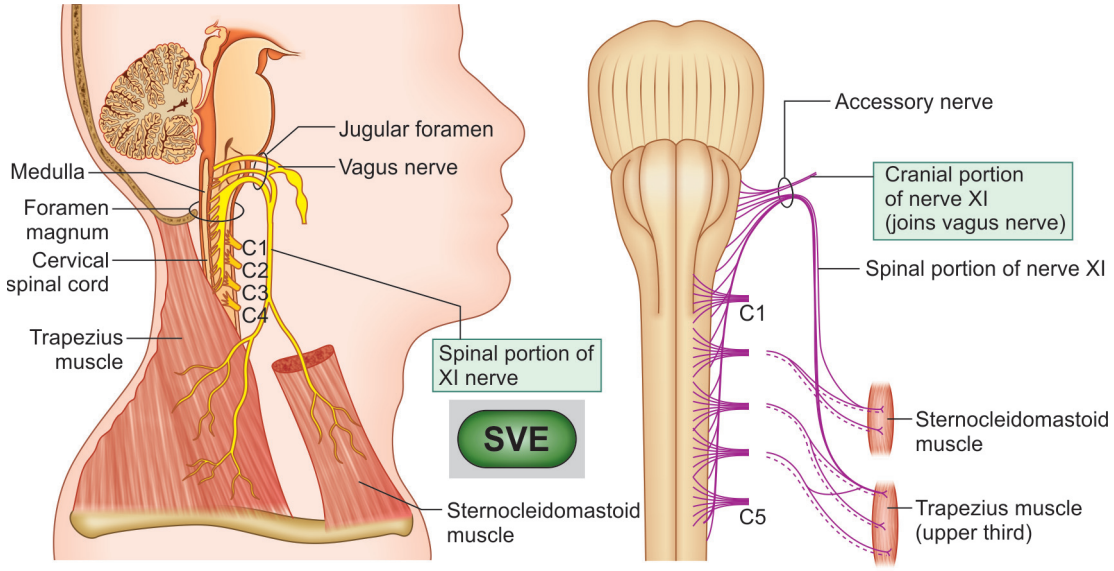


Fig. 20.10: Functional components of XI cranial (accessory) nerve are two: Cranial part supplying muscles of soft palate, pharynx, and larynx—all skeletal muscles of arch origin. The spinal part supplies two skeletal muscles—sternocleidomastoid and trapezius

FUNCTIONAL CRANIAL NERVE NUCLEI AT A GLANCE

Nerves	AFFERENT COLUMNS				EFFERENT COLUMNS		
	SSA	GSA	SVA	GVA	GVE	SVE	SE
I							
II							
III							
IV							
V							
VI							
VII							
VIII							
IX							
X							
XI						?	
XII							

SSA	**Sensations from special sensory organs**: Vision, hearing and equilibrium (balancing)	GVE	**Autonomic** (exclusively parasympathetic): Smooth and cardiac muscles, and glands
GSA	**General sensations:** Touch, pain, temperature, pressure, vibration, and proprioception	SVE	**Skeletal muscles of branchial origin:** Jaws, face, larynx and pharynx
SVA	**Special visceral sensation:** Smell, and taste	SE	**Muscles of somatic/myotome origin:** Orbits and tongue (except palatoglossus)
GVA	**General sensations from viscera**		

Key to functional columns (from dorsolateral to ventrolateral parts separated by sulcus limitans) (Fig. 20.11)

SSA—Special somatic afferent (sensory)—e.g. cranial nerves II for vision and VII (cochlear) nerves (although the II nerve is neither a true cranial nerve nor it is attached to the brainstem)

GSA—General somatic afferent (sensory)—main sensory nucleus of cranial nerve V

SVA—Special visceral afferent (sensory)—special sensations of smell (I) and taste (V, VII, IX, and X)

GVA—General visceral afferent (sensory)—cranial nerves IX an X

GVE—General visceral efferent (motor)—represent preganglionic parasympathetic fibres serving a secretomotor function. Examples are:

- III cranial nerve joined by fibres from ***Edinger-Westphal nucleus*** to supply constrictor papillae muscle
- VII cranial nerve joined by fibres from ***superior salivatory nucleus***
- IX cranial nerve joined with parasympathetic fibres from ***inferior salivatory nucleus***; and
- X cranial nerve having parasympathetic fibres from ***dorsal nucleus of X*** for supply of smooth muscles of thoracic and abdominal organs.

SVE—Special visceral efferent (motor)—always innervate striated muscles (branchial arch derivate of face and neck) represent branchiomotor fibres supplying skeletal muscles derived from pharyngeal (or branchial) arches, Examples are:

- V or trigeminal nerve (muscles derived from first branchial arch: muscles of mastication, anterior belly of digastric, and tensor tympani all of which are supplied by motor nucleus of trigeminal)
- VII or facial nerve (muscles derived from second branchial arch: muscles of facial expression, posterior belly of digastric, and stapedius); and
- IX or glossopharyngeal, X or vagus, and XI or accessory spinal part only (as the cranial part of the nerve travels via branches of vagus).

SE—Somatic efferent (motor)—innervate muscles of somatic origin (involved in locomotion—muscles of limbs, intercostal muscles and of abdominal wall).

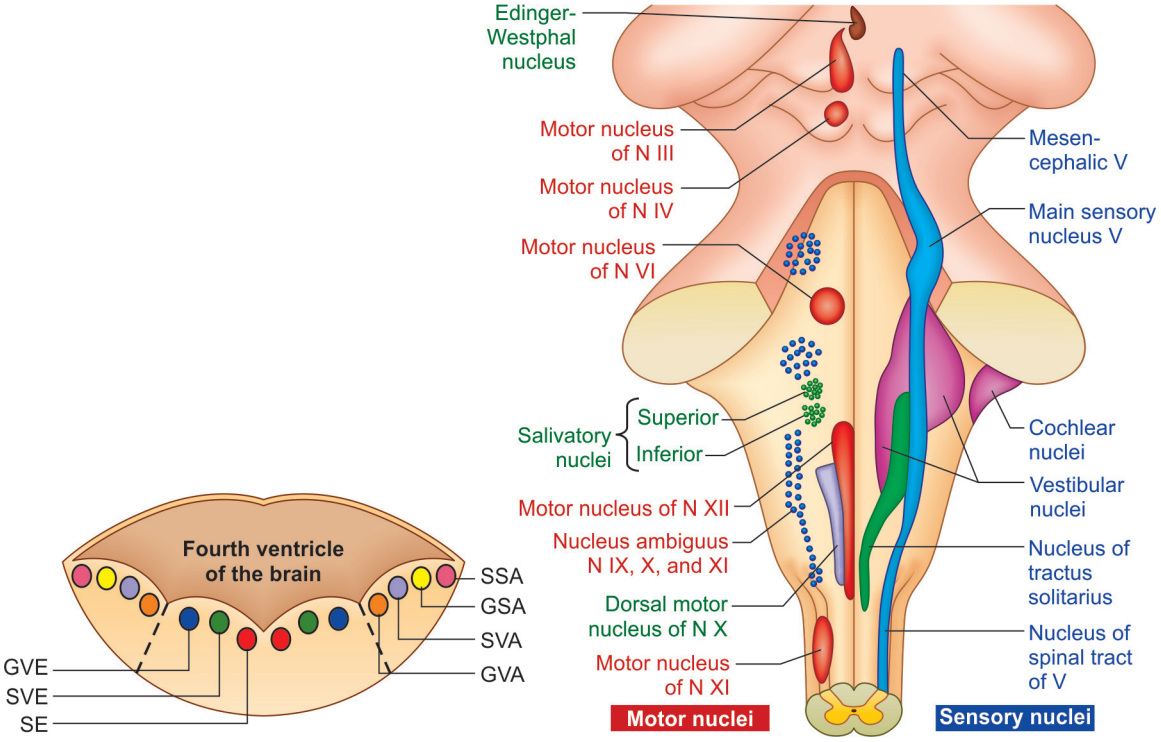


Fig. 20.11: Location of motor (on the left) and sensory (on the right) nuclei of cranial nerves III to XII emerging from the brainstem. Accordingly, the above diagram represents the motor (efferent) and sensory (afferent) functional components in a transverse section of the fourth ventricle