Anatomy of the Brainstem

Comprised of midbrain, pons and medulla oblongata, the brainstem is the central relay station between the cerebrum and the cerebellum. Cranial nerves originate in the brainstem. This article enhances the understanding of the organization and purpose of the brainstem and its components. Antero-posterior orientation of the brainstem is crucial in the pathogenesis of various diseases – the structures involved and the consequent manifestations. The article concludes with a discussion on glossopharyngeal and vagal nerve nuclei.
The brainstem is an indispensable interface between the cerebrum and the cerebellum. It continues as the spinal cord at the cervicomedullary junction after passing through the foramen magnum. The brainstem comprises three components: mesencephalon (midbrain), pons, and medulla oblongata. Sometimes, the diencephalon, which is the caudal part of the forebrain is also included.

**Function of brainstem**

The function of the brainstem is to control the flow of messages between the brain and the rest of the body. The brainstem also regulates the fundamental functions of life such as breathing, heartbeat, blood pressure, control of consciousness, and whether one is awake or sleepy.

It contains both gray matter and white matter. The gray matter is organized into cranial nerve nuclei, the reticular formation and pontine nuclei, while the white matter consists of fiber tracts (axons) mediating information to and fro between the
cerebral cortex, cerebellum, spinal cord, cranial nerves and the peripheral nerves.

Along its entire length, the internal structure of brainstem is organized in three laminae: tectum, tegmentum, and the basis.

The tectum consists of the quadrigeminal plate and the medullary velum responsible for auditory and visual reflexes.

The cranial nerve nuclei are somatotopically organized in the middle layer, that is known as tegmentum. They are arranged from medial to lateral as: somatic motor, visceral motor, visceral sensory and somatic sensory. It is involved in many unconscious homeostatic and reflexive pathways.

The motor pathways travel in the basis, the most anterior part.

**Midbrain**

![Image: "Midbrain (mesencephalon)" by Life Science Databases (LSDB) - from Anatomography. License: CC BY-SA 2.1 JP]

The midbrain (mesencephalon) connects the diencephalon to the pons.

The important components of midbrain are:

**Cranial nerves III (oculomotor) and IV (trochlear) nuclei**

Situated in the midbrain, they are responsible for the control of external ocular movements. The Edinger-Westphal nucleus mediates parasympathetic innervation to the eye and is responsible for the pupillary light reflex.

**Red nucleus**

It conveys dentato-rubro-thalamic fibers to the thalamus from the cerebellum. The rubrospinal tract, part of the extra-pyramidal motor system, originates at the red nucleus.

**Crus cerebri**

Contains the corticospinal tracts as they pass through the cerebral peduncles.

**Substantia nigra**

It conveys dopaminergic fibers to the basal ganglia. Dopamine is produced here. Loss of nigro-striatal facilitation leads to Parkinson’s disease.
The cerebral aqueduct (aqueduct of Sylvius)

The aqueduct marks the transition from the 3rd ventricle to the 4th ventricle. Aqueductal stenosis is a common cause of **congenital obstructive hydrocephalus**.

The peri-aqueductal gray matter

Part of the reticular formation, it helps maintain the consciousness of an individual.

Pons

![Image](https://www.lsdb.org/)  
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Pons (“bridge” in Latin) connects the midbrain above to the medulla oblongata below. The important features of pons are as follows:

1. **Pons, like the rest of the brainstem follows the rule of 4:**
   - Origin to 4 of the cranial nerves: V (trigeminal), VI (abducens), VII (facial) and VIII (vestibulocochlear)
   - 4 medial structures with “M”: motor pathway (corticospinal tract), motor nucleus (abducens), medial lemniscus (somatosensory fibers) and medial longitudinal fasciculus (coordinating III, VI and VIII cranial nerve functions with the spinal cord)
   - 4 lateral structures with “S”: sensory nuclei (trigeminal), spinothalamic tract (pain and temperature), spinocerebellar pathway (unconscious proprioception) and the sympathetic pathway
2. The corticospinal pathway occupies the base of the pons.
3. The middle cerebellar peduncle conveys the ponto-cerebellar pathway.
4. Pons forms the superior half of the floor of the 4th ventricle.
5. The dorsal pons houses the respiratory center that regulates the change from inspiration to expiration.
6. Pons contain nuclei that are responsible for regulation of sleep, respiration, swallowing, bladder control, hearing, equilibrium, taste, eye movement, facial expressions, facial sensation and posture.

Medulla Oblongata
The medulla connects the brainstem with the spinal cord, with transition occurring at the level of the foramen magnum. The important features of the medulla are as follows:

1. It is the origin for the lower cranial nerves: IX (glossopharyngeal), X (vagus), XI (accessory) and XII (hypoglossal) nerves.

2. Three vital centers are vested in the medulla:
   - **Cardiac center**: sets the rate of cardiac contractions
   - **Medullary rhythmicity center**: synchronizes with the pontine respiratory centers to regulate the rhythm of breathing.
   - **Vasomotor center**: controls the vascular tone.

Loss of autonomic drive to respiration is known as "**Ondine's curse**" (central sleep apnea/central hypoventilation syndrome).

3. The corticospinal tracts decussate in the anterior part of the medulla forming the "pyramids".

4. The somatosensory fibers from **gracile and cuneate nuclei** decussate and form the internal arcuate fibers which continue as **medial lemnisci**.

5. The **inferior olivary nucleus**, a major source of input to the cerebellum, is involved in motor control.

6. As nuclei of vagus nerve are found in the medulla, it is a center for circulation and respiration. It is equally important for swallowing and speech.

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**The Reticular Formation**

The reticular formation is a set of interconnected nuclei, found in the brainstem.

- Dorsal tegmental nuclei are found in the midbrain.
- Central tegmental nuclei are found in the pons.
- Inferior nuclei are found in the medulla.

The reticular formation comprises of two components:

- Ascending reticular formation also known as reticular activating system, responsible for sleep-wake cycle, controlling the levels of alertness.
- Descending reticular formation is involved in posture and equilibrium.
Anterior View of the Brainstem

The important structures seen on the anterior aspect of the brainstem are as follows:

**Cranial nerves**

All cranial nerves take origin from the ventral aspect of the brainstem, except the IV cranial nerve which arises dorsally.

- Crus cerebri: They convey the major motor output from the cortex
- Corticospinal and corticobulbar motor fibers in the basis pontis
- Ponto cerebellar fibers
- Medial lemniscus
- Medial longitudinal fasciculus
- Pontine center for lateral gaze
- Reticular formation
- Olivary body, which helps in cerebellar motor functions
- Medullary pyramid, where about 90% of corticospinal fibers decussate

![Image: “Cranial Nerves” by BruceBlaus. License: CC BY 3.0](image)

Posterior View of the Brainstem

The salient anatomical substrates of the posterior surface are:

- The **inferior colliculus** orients the head and ears to auditory stimuli.
- The **superior colliculus** orients the head and eyes to visual stimuli.
- The **trochlear nerve** is the only cranial nerve with dorsal origin. It supplies the superior oblique muscle.
- The **superior cerebellar peduncle** forms the principal motor output of the cerebellum to the ipsilateral limbs.
- The **middle cerebellar peduncle** primarily conveys afferents from the pontine nuclei.
- The **inferior cerebellar peduncle** conveys afferents from the medulla and efferents to the vestibular nuclei
- The floor of the fourth ventricle
The gracie nucleus conveys posterior column sensations (position sense, vibration and fine touch) from the ipsilateral lower extremity.

The cuneatus nucleus conveys posterior column sensations (position sense, vibration and fine touch) from the ipsilateral upper extremity.

The glossopharyngeal nuclei: it is the IX cranial nerve which supplies the pharyngeal plexus and mediates taste sensation from the posterior 1/3rd of the tongue. Stylopharyngeus is the only muscle exclusively supplied by the glossopharyngeal nerve. The following nuclei contribute to the glossopharyngeal nerve fibers:

- The inferior salivatory nucleus: mediates parasympathetic fibers to the parotid gland via the otic ganglion.
- The nucleus ambiguus: supplies branchial motor output to the stylopharyngeus muscle.
- The solitary nucleus conveys sensory input from pharynx, carotid sinus and taste from the posterior 1/3rd of the tongue. The carotid sinus baroreceptors are innervated by the sinus nerve of Hering, which is a branch of glossopharyngeal nerve.

The Vagus nerve nuclei (Latin “wanderer”): Vagus is the longest cranial nerve. Its expanse is inclusive of the posterior cranial fossa to as far as the splenic flexure of the colon. It contributes to the pulmonary, cardiac and esophageal plexuses. The nuclei of origin lie in the medulla and are as follows:

- The dorsal motor nucleus: serves visceral parasympathetic functions
- The nucleus ambiguous: is the branchial motor nucleus to the skeletal muscles of pharynx and larynx.
- The solitary nucleus: is the major sensory nucleus.

Summary

The midbrain, pons and medulla oblongata comprise the brainstem. Except for the first two cranial nerves, which are considered direct extensions of the brain itself, all cranial nerves emanate from the brainstem.

Cranial nerves III and IV arise from the midbrain, V-VIII from the pons and the lower cranial nerves IX-XII from the medulla. Cranial nerve nuclei are topographically arranged so that motor lie medial to sensory.

Brainstem is the major relay station for critical sensory, motor and autonomic information. It plays an important role in the control of cardiac and respiratory function, consciousness and the sleep cycle.

Review Questions on the Brainstem

The correct answers can be found below the references.

1. Which cranial nerve does not originate from the pons?
   A. Cranial nerve III
   B. Cranial nerve VI
   C. Cranial nerve V
   D. Cranial nerve VIII

2. What is the function of nucleus ambiguus?
A. It serves parasympathetic fibers to the Vagus nerve
B. It serves branchiomotor fibers to the Vagus nerve
C. It serves sensory nucleus of the Vagus nerve
D. None of the above.

3. Which of the following is a function of the red nucleus?

A. It serves as sensory relay station before the thalamus
B. It serves as motor relay station from the basal ganglia to the thalamus
C. It serves as relay station from the cerebellum to the thalamus
D. It serves as origin for the red fibers from pons to cerebellum

References


DeJong’s Textbook of Neurology

Correct answers: 1A, 2B, 3C

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