Brainstem Components: Midbrain, Pons and Medulla Oblongata

Comprised of midbrain, pons and medulla oblongata, the brain stem is the central relay station between the cerebrum and cerebellum. Cranial nerves originate in the brain stem. This article enhances understanding of the organization and purpose of the brain stem and its components. Antero-posterior orientation of the brain stem 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.

Organisation of the Brain Stem

The brain stem is the indispensable interface between the cerebrum and the cerebellum. It continues as the spinal cord at the cervicomedullary junction at the foramen magnum. The brain stem comprises of four components: diencephalon, mesencephalon (midbrain), pons, and medulla oblongata.
The fundamental functions of life such as breathing, heartbeat, blood pressure, control of consciousness, and sleep are regulated in the brain stem. It has both gray matter and white matter. The gray matter is organized into cranial nerve nuclei, the reticular formation and pontine nuclei. 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 brain stem is organized in three laminae: tectum, tegmentum, and the basis.

The tectum consists of the quadrigeminal plate and the medullary velum.

The cranial nerve nuclei are somatotrophically organized in the middle layer called tegmentum. From medial to lateral: somatic motor, visceral motor, visceral sensory and somatic sensory.

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

**Midbrain**

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

The important features 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 fibers 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 here.

Crus cerebri

The corticospinal tracts traverse the cerebral peduncles (crus cerebri).

Substantia nigra

It conveys dopaminergic fibers to the basal ganglia. 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 consciousness of an individual.

Pons

Pons (“bridge” in Latin) connects midbrain above to medulla oblongata below. The important features of pons are as follows:

1. Pons, like the rest of the brain stem follows the rule of 4:
   - Origin to 4 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 ponto-cerebellar pathway.
4. Pons forms the superior half of the floor of the 4th ventricle.
5. The dorsal pons houses the respiratory center.

Medulla Oblongata

The medulla connects the brain stem with the spinal cord, the transition being at 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 force and 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 cuneatus nuclei** decussate and form 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.

Anterior View of the Brain Stem

The important structures seen on the anterior aspect of the brain stem are as follows:
**Cranial nerves**

All cranial nerves take origin from the ventral aspect of the brain stem except for 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 ponti
- Ponto cerebellar fibers
- Medial lemniscus
- Medial longitudinal fasciculus
- Pontine centre for lateral gaze
- Reticular formation
- Olivary body: It helps in cerebellar motor functions.
- Medullary pyramid: About 90% of corticospinal fibers decussate here.

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

**Posterior View of the Brain Stem**

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 **gracile nucleus** conveys posterior column sensations (position sense, vibration and fine touch) from ipsilateral lower extremity.
- The **cuneatus nucleus** conveys posterior column sensations (position sense, vibration and fine touch) from 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 ambiguous** 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 brain stem.

Except for the first two cranial nerves, which are considered direct extensions of the brain itself, all cranial nerves emanate from the brain stem.

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.

**Review Questions on the Brain Stem**

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 vagus
   - B. It serves branchiomotor fibers to vagus
   - C. It serves sensory nucleus of vagus
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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