Brain stem

Mesencephalon (Midbrain)
CNS divisions

- **Prosencephalon**
- **Mesencephalon**
- **Rhombencephalon**

- **Telencephalon**
- **Diencephalon**

**Pons**

- **Cerebellum** (\(=\) **Metencephalon**)
- **Medulla oblongata** \(=\) **Bulbus** \(=\) **Myelencephalon**

- **Medulla spinalis**
Midbrain – boundaries & size

- Connects the pons and cerebellum with the forebrain
- The smallest region of the brainstem – 6-7g
- The shortest brainstem segment < 2 cm long
Brainstem divisions

- Mesencephalon (Midbrain)
- Metencephalon (Pons, Cerebellum)
- Myelencephalon (Medulla)
Ventral midbrain

- Cranial Nerve 3
- Cranial Nerve 4
- Cerebral Peduncle
Dorsal midbrain

- Brachium of the Inferior Colliculus
- Brachium of the Superior Colliculus
- Superior medullary velum
Origin of CNS subdivisions

<table>
<thead>
<tr>
<th>Primary vesicles</th>
<th>Secondary vesicles</th>
<th>Adult derivatives</th>
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<tbody>
<tr>
<td>Prosencephalon</td>
<td>Telencephalon</td>
<td>Cerebral hemispheres</td>
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<tr>
<td>(forebrain)</td>
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<td>Lateral ventricles</td>
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<tr>
<td>Mesencephalon</td>
<td>Diencephalon</td>
<td>Neural tissue</td>
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<tr>
<td>(midbrain)</td>
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<td>Cavities</td>
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<tr>
<td>Rhombencephalon</td>
<td>Mesencephalon</td>
<td>Epithalamus</td>
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<tr>
<td>(hindbrain)</td>
<td>Metencephalon</td>
<td>Thalamus</td>
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<td></td>
<td></td>
<td>Hypothalamus</td>
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<tr>
<td></td>
<td></td>
<td>Neurohypophysis</td>
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<tr>
<td>Neural tissue</td>
<td>Cerebral aqueduct</td>
<td>Midbrain</td>
</tr>
<tr>
<td>Cavity</td>
<td></td>
<td>Cerebral</td>
</tr>
<tr>
<td>Spinal cord</td>
<td></td>
<td>aqueduct</td>
</tr>
</tbody>
</table>

- Pons cerebellum
- Medulla
- Rostral 4th ventricle
- Caudal 4th ventricle

Most of 3rd ventricle
Secondary vesicles

A. Myelencephalon
B. Cervical flexure
C. Pontine flexure
D. Metencephalon
E. Mesencephalon
F. Telencephalon
G. Lamina terminalis
H. Diencephalon
I. Telencephalon
Mesencephalon is larger during brain development than in postnatal brain development.

Neural tube folding (5th - 8th wk)
The basal plate → primarily efferent nuclei (CN V, VI, VII, superior salivatory nuclei)
The alar plate → somatic and visceral sensory nuclei (CN V, VIII, pontine nuclei)
Basal plate
- motor nuclei of CN III & CN IV → extraocular muscles (somatic motor)
- Edinger-Westphal nucleus → intraocular muscles (visceral motor)

Alar plate → tectum (colliculi)

Mixed basal & alar plate → substantia nigra, red nucleus
The midbrain has a dorsoventral organization, like the spinal cord.

This is because the 4th ventricle does not extend into the midbrain.
Alar vs basal in midbrain
Estimated time of development of various brain regions

Modified from Bayer SA et al. Neurotoxicology 14:83–144, 1993
Longitudinal zones in the brain stem

**Structures in Midbrain:**
- **Tectum** (=quadrigeminal plate) → superior & inferior colliculi + cerebral aqueduct
- **Tegmentum** → neuronal bodies + tracts passing
- **Basis** = crus cerebri + substantia nigra ("black substance")
  - neuronal axons – corticospinal/corticobulbar fibers
  - neuronal bodies – substantia nigra

<table>
<thead>
<tr>
<th>Region</th>
<th>Contents</th>
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</thead>
<tbody>
<tr>
<td>Tegmentum: anterior floor of the IV ventricle and cerebral aqueduct</td>
<td>Cranial nerve nuclei and all ascending and descending tracts except for tract in basis</td>
</tr>
<tr>
<td>Basis: anterior surface of the tegmentum</td>
<td>Corticospinal, corticonuclear, and corticospinal tracts</td>
</tr>
<tr>
<td>Tectum: posterior surface of the IV ventricle and aqueduct</td>
<td>Cerebellum attached to medulla and pons; superior and inferior colliculi attached to tegmentum of midbrain</td>
</tr>
</tbody>
</table>
Longitudinal zones in the midbrain

cranial
caudal
dorsal
ventral
cerebral aqueduct
tegmentum
basis
Mesencephalic tectum
(=quadrigeminal plate)

- Superior colliculi
- Inferior colliculi
- Cerebral aqueduct
Midbrain - level of superior colliculus

Superior Colliculus
Periaqueductal Gray
Cerebral Peduncles
Red Nucleus
Connections of superior colliculus

(visual) cortex → superior colliculus

eyes → superior colliculus

superior colliculus → thalamus

superior colliculus → spinal cord

superior colliculus → cerebellum
Tectospinal tract - reflexive movement of head and neck; eye movements

Origin: Superior Colliculus
Course: Ventral to MLF, to ventromedial Spinal Cord
Termination: Cervical Spinal cord ventral horn
Laterality: CONTRA (crosses immediately in the dorsal tegmental decussation)
The tectospinal tract carries impulses that control reflex movements of the upper trunk, neck, and eyes in response to visual stimuli.
Midbrain - level of inferior colliculus

- Inferior Colliculus
- Periaqueductal Gray
- Decussation of the Superior Cerebellar Peduncles
- Cerebral Peduncles
The nucleus of the inferior colliculus is a major relay nucleus in the **auditory** pathway.
The **inferior colliculi** are involved in auditory reflexes and in determining the side on which a sound originates.
Midbrain colliculi & brachia

- Superior colliculus
- Inferior colliculus
- Brachium of the Superior Colliculus
- Brachium of the Inferior Colliculus
Cerebral aqueduct (Sylvius)

Obstruction of the cerebral aqueduct may occur congenitally, resulting in a non-communicating hydrocephalus.
Pain control pathways & periaqueductal gray

Ascending pain pathways

Cortico-reticular fibers

Periaqueductal gray

Nucleus raphe magnus

Pain afferent

Dorsal horn

Cerebral aqueduct
Structures in the mesencephalic tegmentum

- Cranial nerve nuclei – CN III, IV
- Reticular formation - nucleus locus ceruleus & other
- Crossing pathways
  - ascending (sensory)
    - superior cerebellar peduncle
    - lemniscal
    - spinothalamic
  - descending (motor)
    - central tegmental tract (basal ganglia/midbrain → inferior olive)
    - rubrospinal tract
    - tectospinal tract
  - other – sympathetic fibers from hypothalamus; medial longitudinal fasciculus
The brainstem is connected to the cerebellum via the cerebellar peduncles

- **Superior cerebellar peduncle (SCP)**
  - Midbrain ↔ Cerebellum
  - SCP is the principal output path of the cerebellum

- **Middle cerebellar peduncle (MCP)**
  - Pons → Cerebellum
  - Connections to Brachium pontis

- **Inferior cerebellar peduncle (MCP)**
  - Medulla oblongata ↔ Cerebellum
  - Connections to Brachium conjunctivum
The midbrain is connected with the cerebellum via SCP. SCP represents the main cerebellar output to the thalamus and red nucleus.
Major ascending and descending tracts in the mesencephalic tegmentum

Lemniscal system
**Corticobulbar tracts**

**Motor input to:**
- Reticular formation – mesencephalic
- Red Nucleus
- Cranial Nerve motor nuclei – III, IV

Note – No direct connections from the primary motor cortex to III, IV, and VI; these nuclei get input from frontal and parietal cortex
Cranial nerves – sensory nuclei

- Mesencephalic n. of CN V
- Principal n. of CN V
- Spinal (descending) n. of CN V
- Superior vestibular n. (CN VIII)
- Lateral vestibular n. (CN VIII)
- Cochlear n. (CN VIII)
- Inferior vestibular n. (CN VIII)
- Medial vestibular n. (CN VIII)
- Solitary n. (CN VII, IX & X)
Cranial nerves – motor nuclei

- Edinger-Westphal n. (CN III)
- Oculomotor n. (CN III)
- Trochlear n. (CN IV)
- Motor n. of CN V
- Abducens n. (CN VI)
- Facial n. (CN VII)
- Superior (CN VII) & Inferior (CN IX) salivatory n.
- Dorsal motor n. (CN IX & X)
- Ambiguus n. (CN IX & X)
- Hypoglossal n. (CN XII)
- Spinal accessory n. (CN XI)
Cranial nerve nuclei in brain stem

<table>
<thead>
<tr>
<th>Name</th>
<th>Nerve</th>
<th>Nuclei</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oculomotor</td>
<td>III</td>
<td>Oculomotor, Edinger–Westphal</td>
<td>midbrain</td>
</tr>
<tr>
<td>Trochlear</td>
<td>IV</td>
<td>Trochlear</td>
<td>pons</td>
</tr>
<tr>
<td>Trigeminal</td>
<td>V</td>
<td>Main sensory, spinal (descending), mesencephalic, motor (masticatory)</td>
<td></td>
</tr>
<tr>
<td>Abducens</td>
<td>VI</td>
<td>Abducens</td>
<td>pons</td>
</tr>
<tr>
<td>Facial</td>
<td>VII</td>
<td>Facial, superior salivatory, gustatory (solitary)**</td>
<td></td>
</tr>
<tr>
<td>Vestibulocochlear</td>
<td>VIII</td>
<td>Cochlear (2 nuclei), vestibular (4 nuclei)</td>
<td>medulla</td>
</tr>
<tr>
<td>Glossopharyngeus</td>
<td>IX</td>
<td>Ambiguus*, inferior salivatory, solitary**</td>
<td></td>
</tr>
<tr>
<td>Vagus</td>
<td>X</td>
<td>Dorsal motor, ambiguus**, solitary*</td>
<td></td>
</tr>
<tr>
<td>Accessory</td>
<td>XI</td>
<td>Spinal accessory (C1–5), ambiguus**</td>
<td></td>
</tr>
<tr>
<td>Hypoglossal</td>
<td>XII</td>
<td>Hypoglossal</td>
<td></td>
</tr>
</tbody>
</table>

** The solitary nucleus is common for CN VII, IX, and X
* The ambiguus nucleus is common for CN IX, X, and XI
**CN III: Oculomotor**

**Origin:** Oculomotor nucleus (motor), Edinger-Westphal nucleus (Psym)

**Course:** Interpeduncular Fossa, Cavernous Sinus, Sup Orb Fissure

**Termination:** MR, SR, IR, IO; Levator Palpebrae, Constrictor Pupillae (Psym)

**Laterality:** Ipsilateral to extraocular muscles; bilateral to parasym pathetic ganglia
CN III: Oculomotor

Edinger–Westphal

motor
CN III: Oculomotor

Motor
- somatic
- visceral

Sensory
- visceral
- somatic

extraocular skeletal muscles
Motor innervation of the eye

Striated (extraocular muscles)

Ciliary ganglion

To striated (extraocular) muscles

To smooth (intraocular) muscles

Oculomotor nucleus

Trochlear nuclei

Abducens nucleus

Edinger-Westphal nucleus

Ciliary ganglion

Oculomotor nerve

Nerves
Striated (extraocular muscles) - innervation

All other – CN III
CN III: Oculomotor
CN IV: Trochlear

Origin: Trochlear Nucleus

Course: Quadrigeminal Cistern, Ambient Cistern, Cavernous Sinus, Sup Orb Fissure

Termination: Superior oblique muscle

Laterality: Contralateral
CN IV: Trochlear

The nucleus is at the level of the SCP decussation.

The nerve exits caudal to the inferior colliculus. Contralateral.
CN IV: Trochlear

- Trochlea (IV)
- Superior oblique muscle (IV)
- Optic nerve (II)
- Infundibulum
- Cerebral peduncle
- Inferior colliculus
- Trochlear nerve (IV)
- Trochlea
- Superior oblique muscle (IV)
- Superior straight muscle (III)
- Lateral straight muscle (VI)
- Levator muscle of upper eyelid (III) (sectioned)
Red nucleus

- Ovoid mass ~5 mm in diameter
- Dorsomedial to the substantia nigra
- Pinkish in fresh preparations → its neurons contain iron pigment
Connections of the red nucleus

**Afferent connections**
- Corticorubral tract
- Red nucleus
- Brachium conjunctivum

**Efferent connections**
- MESENCEPHALON
- Red nucleus
- Central tegmental tract
- Inferior olive
- BRACHIUM CONJUNCTIVUM
- CEREBELLUM
- Restiform body
- Lateral reticular nucleus
- Rubrospinal tract
- DEEP CEREBELLAR NUCLEI

**CEREBRAL CORTEX**

**MESENCEPHALON**

**CEREBELLUM**

**SPINAL CORD**
Rubrospinal Tract – movement of upper limbs

**Origin:** Red nucleus
**Course:** Dorsolateral white matter with LCST in spinal cord
**Termination:** Cervical Spinal cord ventral horn
**Laterality:** CONTRA (crosses immediately in the ventral tegmental decussation)
Rubrospinal tract

The red nucleus receives cortical input; Rubrospinal fibers project on the same spinal cord laminae as does the corticospinal tract → **indirect** corticospinal tract
The CN III motor fiber pass through the red nucleus.

Lesions of the red nucleus result in contralateral tremor.
Structures in the mesencephalic basis

- Neuronal axons
  - Cortico-ponto-cerebellar fibers
  - Corticospinal fibers
  - Corticobulbar fibers
- Neuronal bodies - Substantia nigra
Corticospinal and corticobulbar tracts

- Corticobulbar fibres
- Corticospinal fibres
- Motor cranial nerve fibres
- Decussation of pyramids
- Motor spinal nerve fibres

Corticospinal tract

Origin: Primary motor cortex (BA 4)
Course: Post Limb IC, Pyramids
Termination: Spinal cord ventral horn
Laterality: CONTRA (lateral), IPSI (anterior)
Corticopontine tract

Origin: Premotor, primary motor, and primary somatosensory cortex
Course: Internal Capsule (A/P), cerebral peduncles, Pons
Termination: Pontine nuclei
Laterality: Ipsilateral
Somatotopic organization of corticospinal & corticobulbar tracts
Substantia nigra (SN)

- Superior colliculus
- Aqueduct of midbrain
- Periaqueductal gray
- Oculomotor nucleus (CN III)
- Red nucleus
- Substantia nigra
- Cerebral peduncle

Pars compacta
Pars reticulata
Neurons in SN

- **Pars compacta (SNpc)** – dorsal, containing neuromelanin → dopamine

- **Pars reticulata (SNpr)** – ventral, iron compounds → Ach, GABA; SNpr extends rostrally as far as the subthalamic region, and is considered to be homologous with the medial segment of the globus pallidus, which it resembles structurally
TH staining of DAergic neurons in SN pars compacta
Substantia nigra modulates the loops between cortex-basal ganglia
Damage of SNpc neurons leads to Parkinson’s disease.

Lewy bodies in SNpc neuron, H&E
Upper midbrain

- Superior colliculus
- Brachium of the inferior colliculus
- Anterolateral system
- Medial lemniscus
- Edinger-Westphal nucleus
- Oculomotor nucleus
- Oculomotor nerve (CN III)
- Aqueduct of midbrain
- Periaqueductal gray
- Reticular formation
- MLF
- Red nucleus
- Substantia nigra
- Pars compacta
- Pars reticulata
- Parieto-, temporo- and occipito-pontine fibers
- Cortico-spinal tract
- Fronto-pontine fibers
Blood supply of midbrain

- **Basilar artery → paramedian branch**
  - oculomotor (III) nerve nucleus
  - red nucleus (RN)
- **Superior cerebellar artery → tectum**
- **Posterior cerebral artery**
  - basal branch → cerebral peduncle (CP)
  - dorsolateral branch → spinothalamic tract (ST), medial lemniscus (ML), and SCP
Blood supply of midbrain – clinical syndromes

- Inability to move the eyes up or down
- Tremor + sensory deficiency
- Hemiparesis + CN III paralysis

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Blood supply of midbrain – clinical syndromes

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