Internal Organisation of the Brainstem

Major tracts and nuclei of the brainstem (Notes)
The brainstem is the major pathway for tracts and houses major nuclei, that contain sensory, motor and autonomics to the head and elsewhere. Associated with these nuclei are tracts within the brainstem. The brainstem also has connections with the cerebellum via the peduncles. The reticular formation makes up most of the brainstem tegmentum and is diffuse. It serves various functions (discussed later). Collectively, the brain stem functions much like the spinal cord, but for the head.

Location of the brainstem (Nolte 5th Ed pp 263 Fig 11.1)
The spinal cord continues rostrally into the brainstem, which also is associated with the diencephalon. It is located in the posterior cranial fossa along with the cerebellum. The spinal cord traverses through the foramen magnum to ‘become’ the brain stem.

Divisions of the brain stem (Nolte 5th Ed pp 264 Fig 11-2, Netter Plate 108)
The brain stem is subdivided into three major sections (caudal → rostral): medulla, pons & midbrain. These develop from: mes, met, myelencephalon respectively. Met + Myelencephalon = Rhombencephalon. Cranial nerves I & II do not exit from the brainstem. They exit in the cranial cavity via the cribiform plate and optic canal. Cranial nerves III-XII exit from the brain stem. They respectively exit points are: midbrain: III – IV, pons: V-VIII, medulla: IX-XII (Netter Plate 108).

Ventricular system in the brainstem (Nolte 5th Ed pp 264-267 Fig 11-3/11-4)
The medulla is the continuation of the spinal cord rostrally. The central canal of the spinal cord connects to the fourth ventricle of the medulla via the obex. The fourth ventricle expands larger as you move towards the rostral medulla. The caudal medulla is called the ‘closed portion’, whilst the rostral medulla is called the ‘open portion’. The fourth ventricle expands larger in the caudal and mid pons area, before tapering off in the rostral pons area. The tapered portion continues in the midbrain as the cerebral aqueduct.

Regions of the brainstem (Nolte 5th Ed pp 267 Fig 11-3/11-4 Netter Plate 109)
At any give brainstem level rostral to the obex, if you take a transverse section (Fig 11-4), you will see three regions. In the Figure mentioned, anterior refers to left and posterior refers to right. The three regions are: 1) area posterior to ventricular system 2) area anterior to ventricular system 3) area anterior to ventricular system which has large structures associated with it.

The midbrain is the only region where there is considerable amount of neural tissue posterior to the ventricular system (i.e.: cerebral aqueduct). This portion is called the tectum (“roof”). It is made up of the superior + inferior colliculi. The area posterior to the fourth ventricle in the pons and rostral medulla is called the superior and inferior medullary velum (associated with the cerebellum). The are anterior to the ventricular space is called the tegmentum (“covering”). The tegmentum consists of the reticular formation, cranial nerve nuclei + tracts, ascending and some descending pathways from/to spinal cord. The structures associated with the anterior brainstem consist of fibres from cerebral cortex descending to the spinal cord, fibres to the cranial nerve or pontine nuclei.

Refer to Fig 11.5 where the tectum, tegmentum and anterior structures are shown clearly. Knowing where a particular nuclei/tract is within these three regions may help you identify them quite easily.

Identifying divisions of the brain stem (Notes)
The convention is that **posterior/dorsal** is at the top and **anterior/ventral** is at the bottom. This follows the same pattern from the spinal cord.

Note when studying MRI and CT scans, the opposite convention is applied. **Posterior/dorsal** is at the bottom & **anterior/ventral** is at the top.

Spinal Cord (Netter Plate 151)

We have done this to death, so I wont dwell on it at all.

For each of the sections below: refer to the Chapter "Atlas of the Human Brainstem. Identification of each major structure is only necessary, you do not need to describe it. The description below is only for orientation.

Caudal Medulla (Nolte 5th Ed pp 268-271 Fig 11-6-9 Netter Plate 108)
Refer to Fig 11.7 mainly while reading this:
Anatomically, the caudal medulla extends from the caudal end of the decussation of pyramids to the obex (caudal end of fourth ventricle). Anteriorly/Ventrally, it consists of the pyramids – convey the corticospinal tracts (originated from the ipsilateral cerebral cortex). The posterior/dorsal aspect consists structures analogous to the spinal cord. Lissauer's tract and dorsal horn replaced by the spinal trigeminal tract and spinal trigeminal nucleus. Fasciculus gracilis and cuneatus are still present, but are gradually replaced by nucleus gracilis + cuneatus. The spinothalamic tract is also found in the dorsal aspect, maintaining the same anterolateral position as it did in the spinal cord. The spinocerebellar tracts (unconscious proprioception) are also found in the dorsal/posterior aspect of the transverse section. The dorsal aspect also contains CN nuclei IX, X, & XII.

Rostral Medulla (Nolte 5th Ed pp 271 Fig 11-9)
Refer to Fig 11.9 mainly while reading this:
The rostral medulla extends rostrally from the obex to the rostral wall of the lateral recess (i.e.: inferior cerebellar peduncle → Fig 11-3). Anteriorly/Ventrally: the obex is coincident with the olives that houses the inferior olivary nucleus. Medial to this nucleus it the medial lemniscus along the dorsal ventral axis. The rostral medulla still houses the pyramids (corticospinal tracts from ipsilateral cerebral cortex). On the posterior/dorsal aspect of the transverse section, you see the following: fourth ventricle (anterior most), inferior cerebellar peduncle (Fig 11-3A). The spinothalamic tract is located in the anterolateral portion of the tegmentum (For tegmentum refer to Fig 11-5). The dorsal aspect also houses many CN nuclei (pp 376) such as: V (spinal trigeminal nucleus), VIII, IX, X, XII.

Refer to MRI through rostral medulla and identify some structures (Weir CD)

Caudal Pons (Nolte 5th Ed pp 272 Fig 11-10 + pp 378)
Refer to Fig 11-10 mainly while reading this:
The caudal pons extends from the rostral wall of the lateral recess of the fourth ventricle (approx. inferior cerebellar peduncle) to the rostral edge of the middle cerebellar peduncle (Fig 11-3). Ventrally/Anteriorly the corticospinal tract is see to occupy in a space within the surrounding pontine nuclei. The pyramidal tracts becomes dispersed in the caudal pons area, and forms longitudinal and transverse bundles of fibres. Interspersed within these bundles is the pontine nuclei. The transversely oriented fibres are the pontocerebellar fibres. Dorsolaterally: you identify the middle cerebellar peduncle which houses the fibres from the pontine nuclei, which travel to the cerebellum. Dorsally/Posteriorly is the 4th ventricle. Just below the floor of the fourth ventricle, you see the medial longitudinal fasiculus. The medial lemniscus assumes a more oval shape compared to the rostral medulla. The dorsal aspect houses the following CN nuclei (pp 378): V (spinal trigeminal nucleus). VI, VII, VIII.

Refer to MRI through caudal-mid pons and identify some structures (Weir CD)

Mid-Rostral pons (Nolte 5th Ed pp 273 Fig 11-12 + pp 380)
The rostral pons begins from the rostral edge of the middle cerebellar peduncle to the beginning of the cerebral aqueduct. The rostral pons is mainly concerned with motor function. Ventrally/Anteriorly you find the corticospinal tract arranged as longitudinal bundles of fibres. The pontine nuclei still persist along with the pontocerebellar fibres (transverse pontine fibres). Dorsally/Posteriorly: the fourth ventricle still persists but is now narrower as it approaches the cerebral aqueduct, lateral to the fourth ventricle is the superior cerebellar peduncles. On its surface runs the anterior spinocerebellar tract in the mid pons. The medial lemniscus gradually becomes more flattened along a medial-lateral axis (feet located laterally – still maintaining the homunculus). The spinothalamic tract persists just lateral to this in the

mid and rostral pons. The lateral lemniscus is intimately associated with the spinothalamic tract, just lateral to the medial lemniscus (pp 380).

Caudal Midbrain (Nolte 5th Ed pp 274 Fig 11-13 + pp 382)
The caudal midbrain extends from the origin of Trochlear nerve to the intercollicular groove (between superior and inferior colliculus). Ventrally/Anteriorly: cerebral peduncles through which corticospinal tracts travel through, substantia nigra is located dorsomedially – contains dopaminergic neurons whose axons terminate in the caudate nucleus and putamen (pp 382). Dorsally/Posteriorly: cerebral aqueduct, decussation of superior cerebellar peduncles. The inferior colliculus is a prominent nuclear mass just lateral to the cerebral aqueduct. The medial lemniscus curves a bit dorsally and the spinothalamic tract extends from this projection lying on the surface of the brainstem. The trochlear nucleus is just located inferiorly to the cerebral aqueduct (a small mass seen on pp 382).

Rostral midbrain (Nolte 5th Ed pp 274 Fig 11-14 + pp 384)
The rostral midbrain essentially consists of the superior colliculus. It extends from the intercollicular groove to the posterior commissure. Ventrally/Anteriorly: the cerebral peduncles (descending corticospinal, corticobulbar, corticopontine fibres) are visible quite easily ventrolaterally, the substantia nigra is visible just medial to the cerebral peduncles. The red nucleus (pp 384) is located just superomedially to the substantia nigra. Axons from here project to the inferior olivary nucleus via the tegmental tract. All of these in the ventral aspect of the rostral midbrain have a motor function. Dorsally/Posteriorly: the cerebral aqueduct still persists, the superior colliculus is located at a similar place to the inferior colliculus in the caudal midbrain. The medial lemniscus and spinothalamic tracts form a continuous curved band of fibres visible clearly just superior to the substantia nigra. The gray mater surrounding the cerebral aqueduct is called periaqueductal gray mater (descending pathway). CN III nuclei is located at the midline just below the periaqueductal gray mater.

Refer to MRI through rostral pons and identify some structures (Weir CD)

Major tracts traversing the brainstem: corticospinal, spinothalamic, medial lemniscus (Refer to Chapter: "Atlas of Human Brain" Nolte 5th Ed).

Go through each of the sections and identify the following: corticospinal, medial lemniscus and spinothalamic.

Brainstem connections with the cerebellum: cerebellum peduncles (Nolte 5th Ed pp 374-384)
The cerebellar peduncles connect the brainstem to the cerebellum. This way, inputs/outputs from/to cerebellum can enter/exit the brain stem at various levels. Inspecting the transverse sections you can easily make out the following: superior cerebellar peduncle (caudal midbrain), middle cerebellar peduncle (pons), inferior cerebellar peduncle (rostral medulla).

Spinal nerves (Notes)
Spinal nerves are formed by ventral and dorsal roots. Ventral roots consist of efferent fibres. These fibres can be general somatic efferents (supplying skeletal muscle) or general visceral efferents travelling via autonomics (sympathetic T1-L2, parasympathetics S2-S4) (supplying organs + glands etc).

Dorsal roots consist of afferent fibres. These fibres can be general somatic afferents (sensory from skeletal muscles) or general visceral afferents via autonomics (sympathetic T1-L2, parasympathetics S2-S4) (sensory from organs + glands).

Cranial nerves (Notes)
Similar to spinal nerves. Refer to Lecture notes.

Cranial Nerves (Netter Plate 108)
Midbrain: III, IV
Pons: V, VI, VII, VIII
Medulla: IX, X, XI, XII

CN nuclei in rostral medulla (Refer to pp 376)
CN nuclei in caudal pons (Refer to pp 378)

Reticular formation (Nolte 5th Ed pp 276 Fig 11-6)
The reticular formation makes up most of the tegmentum and is diffusely located. At most levels along the brain stem the reticular formation is divided longitudinally into three zones – medial-lateral axis. These zones are actually cell columns, traversing the brain stem. The raphe nuclei are thin columns of cells immediately adjacent to the midline (median). The medial zone (paramedian) is just adjacent to the midline raphe nuclei and is the source for most ascending and descending projections form the reticular formation. The lateral zone (lateral cell columns) is adjacent to the paramedian zones and mainly concerns with cranial nerve reflexes and visceral f^ns. The reticular formation has a high interconnectivity because one cell may have several inputs and give rise to several outputs.

Functions of the reticular formation (Nolte 5th Ed pp 276)
The reticular formation subserves in the following functions: motor, sensory, visceral, reticular activating system & monoaminergic systems (use various monoamines such as: dopamine, noradrenaline, serotonin and adrenaline etc).

Motor functions of the reticular formation (Nolte 5th Ed pp 276 Fig 11-16)
The medial zone of the reticular formation at the pons and medullary levels gives rise to two reticulospinal tracts. These tracts are the alternate routes (to the pyramidal tract) that contain UMN controlling LMNs in the spinal cord. Reticulospinal tracts arising from the pons travel with the ipsilateral MLF via the anterior column to the spinal cord gray matter. The medullary reticulospinal tracts descend bilaterally to the anterior portion of the lateral column to the spinal cord gray mater. Certain reticular formation areas are closely related to the cerebellum involved in motor control (i.e.: lateral reticular nucleus). The paramedian pontine reticular formation consists of UMNs connecting to LMNs of eye muscles – involved in lateral gaze (Lecture 10 – Orbit & Control of eye movements).

Sensory functions of the reticular formation (Nolte 5th Ed pp 277 Fig 11-17)
The reticular formation can suppress or facilitate the experience of pain. The part of the reticular formation that does this is the periaqueductal gray mater. Stimulation of the periaqueductal gray mater can suppress the pain pathways. PAG mater receives inputs from spinomesencephalic fibres about the level of noxious stimuli, inputs are also received from hypothalamus and cortical areas which are relevant to whether the pain-control system is activated or suppressed. Efferents from the PAG mater project to one of the nucleus raphe magnus of pons. Efferents from here project to the superficial lamina of the posterior horn via the posterior portion of the lateral column.

Reticular formation functions: visceral regulation (Nolte 5th Ed pp 278)
Visceral information reaches the reticular formation which causes appropriate responses depending on the environmental changes occurring, by projecting to appropriate autonomic nuclei of the brainstem and spinal cord. Centers controlling heart rate and blood pressure have been identified in the medullary reticular formation, whilst those controlling respiration have been identified in the medulla.

Reticular activating system and monoaminergic systems (Nolte 5th Ed pp 279)
The reticular formation forms ascending pathways that terminate in the thalamus and cortex. Neurons in the reticular formation of the midbrain and pons collect sensory information (e.g.: pain) and project to the intralaminar nuclei of the thalamus. Fibres from the thalamus project to various cortical areas. This causes a state of heightened "alert" in response to the sensory stimuli (e.g.: pain). This, together, with the monoaminergic systems (monoamines include: dopamine, adrenaline/noradrenaline, ACh, serotonin) is important in maintaining a normal state of consciousness. The portion of the brainstem reticular formation that provides the input to the cerebral cortex (via thalamus) is called: ascending reticular activating system (ARAS).
Blood supply of the brain stem (Nolte 5th Ed pp 286 Fig 11-25, Netter Plate 131/133)

The brainstem is entirely supplied by the vertebrobasilar system. This system is evident on the ventral surface of the brain stem.

Blood supply to medulla (Nolte 5th Ed pp 286, Netter Plate 131/133)
The anterior and lateral portions are supplied by the anterior spinal artery and some branches of the vertebral artery. The posterior portions are supplied by the posterior spinal artery and branches of the posterior inferior cerebellar artery (PICA).

Blood supply to pons (Nolte 5th Ed pp 286, Netter Plate 131/133)
The pons is supplied by the paramedian and circumferential branches of the basilar artery.

Blood supply to midbrain (Nolte 5th Ed pp 286, Netter Plate 131/133)
The midbrain is mainly supplied by the posterior cerebral artery (terminal branch of basilar artery). Direct branches from the basilar artery and superior cerebellar artery also contribute to the midbrain's blood supply.