17

Brainstem

CHAPTER SUMMARY

General arrangement of cranial nerve nuclei
Background information
Study guide
Overview of three pathways in the brainstem
C1 segment of the spinal cord
Spinomedullary junction
Middle of the medulla oblongata
Upper part of the medulla oblongata
Pontomedullary junction
Mid-pons
Upper pons
Lower midbrain
Upper midbrain
Midbrain–thalamic junction
Orientation of brainstem slices in magnetic resonance images
Epilogue

STUDY GUIDELINES

1. This chapter largely deals with the identification of structures in transverse sections of the brainstem. A separate study guide is provided for the sections.
2. Four brainstem decussations should recall those described in Box 3.1.
3. Note that in magnetic resonance images, brainstem orientation is the reverse of the anatomic convention.

GENERAL ARRANGEMENT OF CRANIAL NERVE NUCLEI

In the thoracic region of the developing spinal cord, four distinct cell columns can be identified in the grey matter on each side (Figure 17.1A, B). In the basal plate the *general somatic efferent (GSE) column* supplies the striated muscles of the trunk and limbs. The *general visceral efferent (GVE) column* contains preganglionic neurons of the autonomic system. In the alar plate the *general visceral afferent (GVA) column* receives afferents from thoracic and abdominal organs. A *general somatic afferent (GSA) column* receives afferents from the body wall and the limbs.

In the brainstem these four cell columns can be identified; but they are fragmented, and not all contribute to each cranial nerve. Their connections are as follows.

- *GSE column*. Supplies the striated musculature of the orbit (via the oculomotor, trochlear, and abducens nerves) and tongue (via the hypoglossal nerve).
- *GVE column*. Gives rise to the cranial parasympathetic system introduced in Chapter 13. The target ganglia are the ciliary, pterygopalatine, otic, and submandibular ganglia in the head and neck and the vagal ganglia in the neck, thorax, and abdomen.
- *GVA column*. Receives from the visceral territory of the glossopharyngeal and vagus nerves.
- *GSA column*. Receives from skin and mucous membranes, mainly in trigeminal nerve territory whose most important components are the skin and mucous membranes of the oronasofacial region, and the dura mater.

Three additional cell columns (Figure 17.1C, D) serve branchial arch tissues and the inner ear, as follows.

- *Special visceral (branchial) efferent (SVE) column*. To branchial arch musculature of the face, jaws, palate, larynx, and pharynx (via facial, trigeminal, glossopharyngeal, vagus, and cranial accessory nerves). These striated muscles have visceral functions in relation to food and air intake (hence, *visceral*).
- *Special visceral afferent (SVA) column*. Receives from taste buds located in the endoderm lining the branchial arches.
- *Special somatic afferent (SSA) column*. Receives from vestibular (balance) and cochlear (hearing) organs in the inner ear.

Figure 17.2 shows the position of the various nuclei in a dorsal view of the brainstem.

In this chapter, details of the internal anatomy of the brainstem accompany nine representative transverse sections and their captions. Connections (direct or indirect) with the *right* cerebral hemisphere have been highlighted in accordance with information to be provided.

BACKGROUND INFORMATION

As stated earlier, exteroceptive and conscious proprioceptive information is transferred (by anterolateral and dorsal column–medial lemniscal pathways, respectively) from the left trunk and limbs to the right cerebral hemisphere. It was also explained that corticospinal fibres of the pyramidal tract arising from motor areas of the cerebral cortex supply contralateral ventral horn cells and give a small ipsilateral supply of similar nature, and that those arising from the parietal lobe project to the contralateral dorsal grey horn.

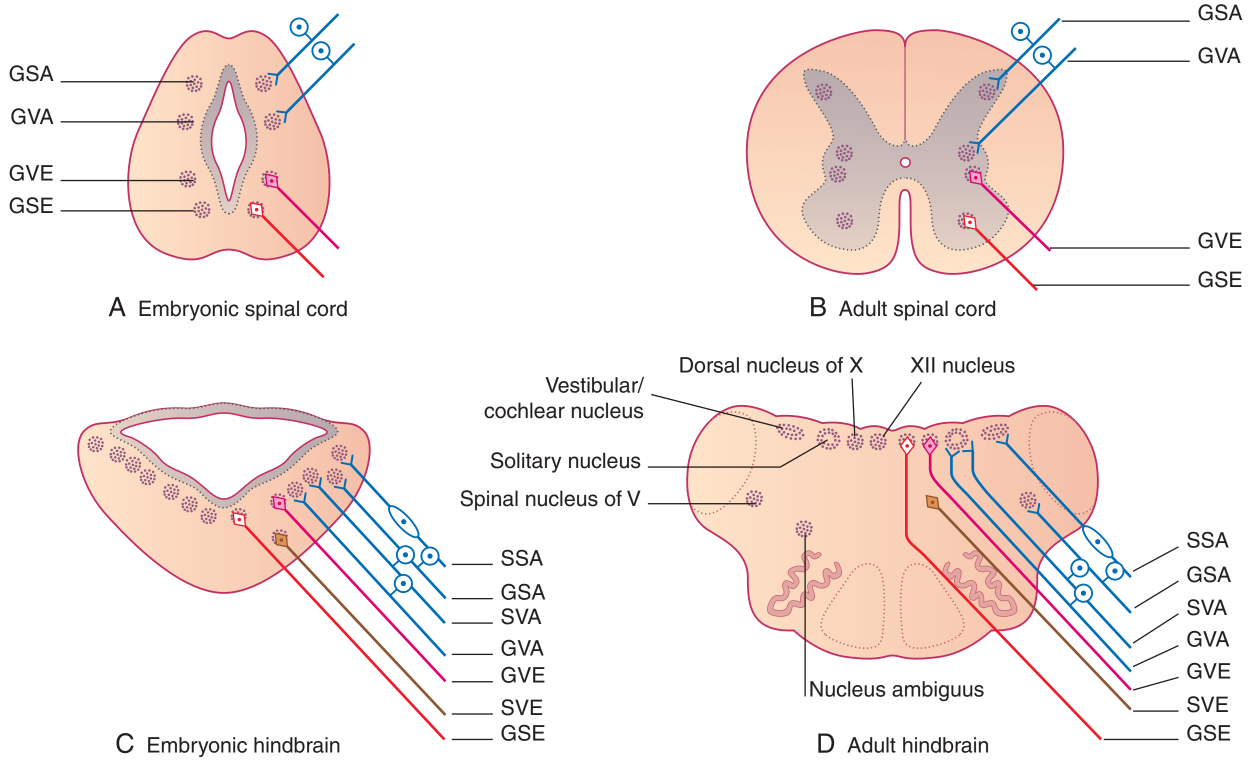

FIGURE 17.1 Cell columns of the spinal cord and brainstem. **(A)** Embryonic spinal cord. **(B)** Adult spinal cord. **(C)** Embryonic hindbrain. **(D)** Adult hindbrain. *Afferent cell columns:* GSA, general somatic afferent; GVA, general visceral afferent; SSA, special somatic afferent; SVA, special visceral afferent. *Efferent cell columns:* GSE, general somatic efferent; GVE, general visceral efferent; SVE, special visceral efferent.

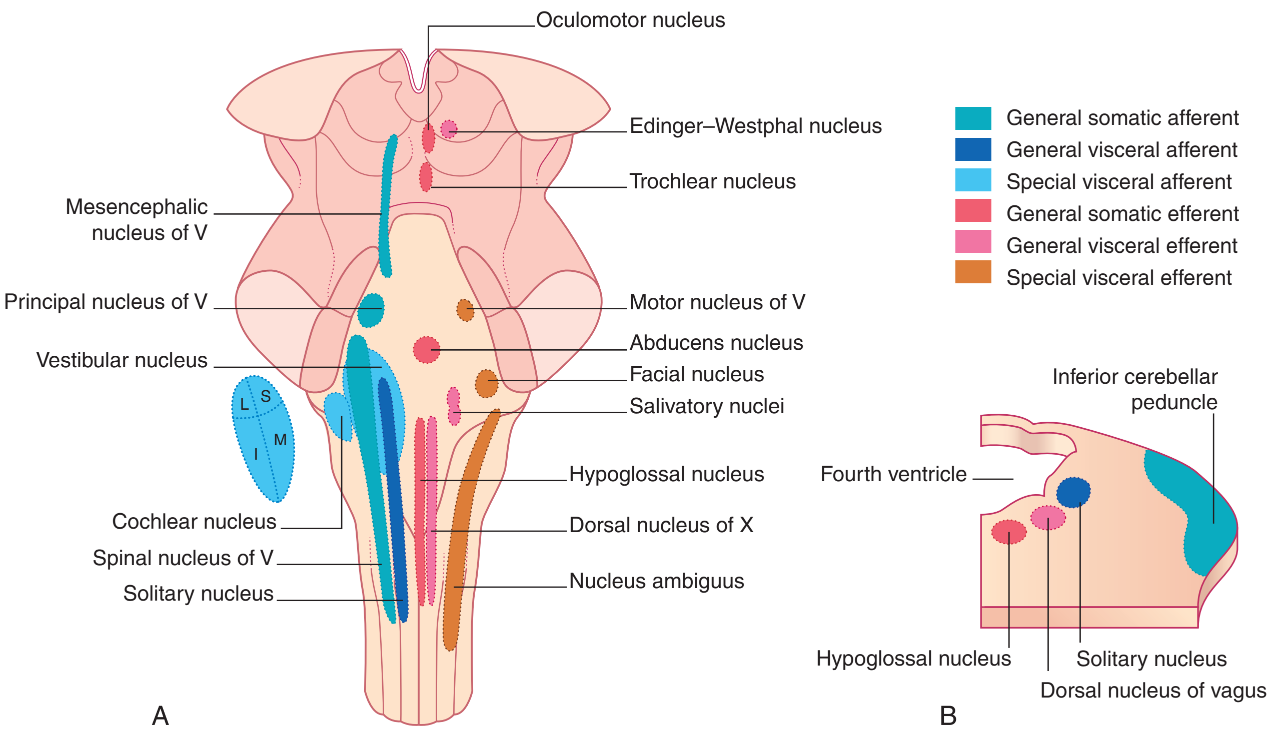

FIGURE 17.2 Dorsal view of adult brainstem, showing position of cranial nerve cell columns. L, S, I, M, lateral, superior, inferior, medial vestibular nuclei (the vestibular nuclei are projected to the side for clarity).

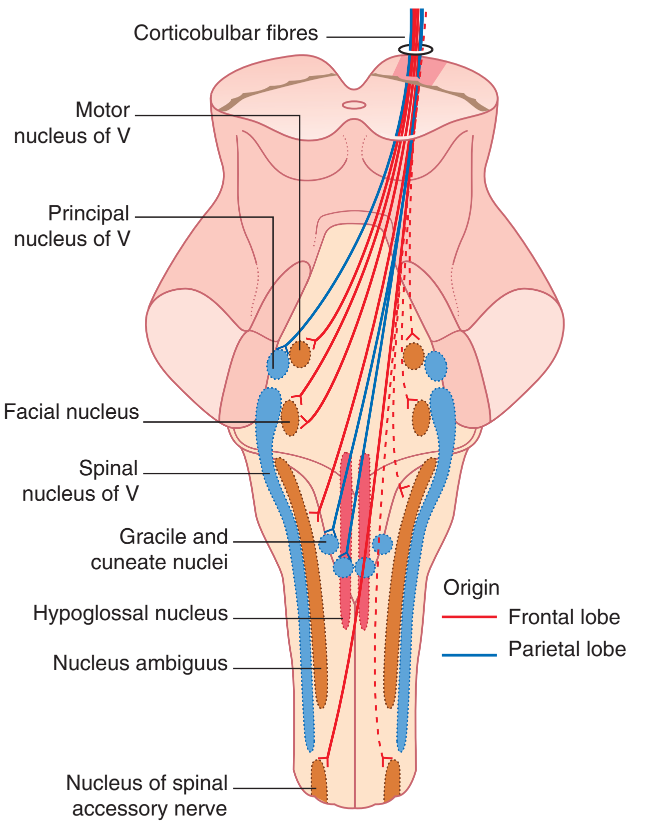

FIGURE 17.3 Dorsal view of brainstem, showing distribution of corticobulbar fibres from the right cerebral cortex.

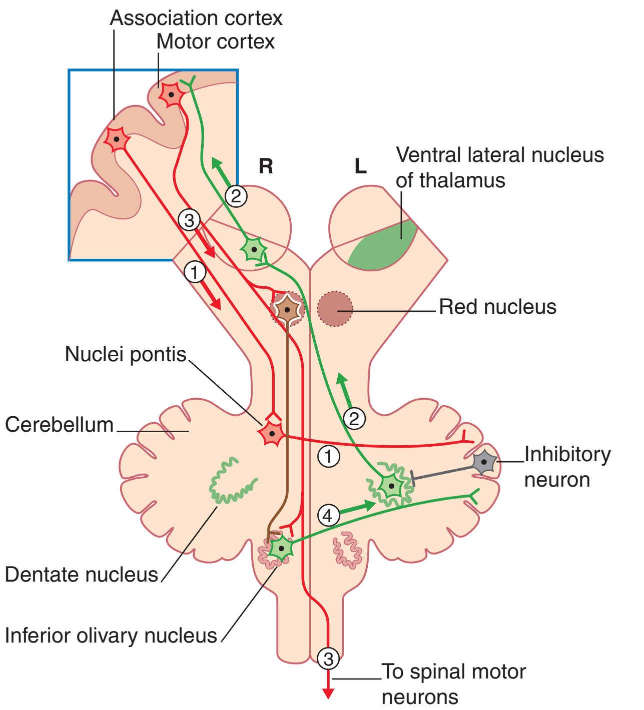

FIGURE 17.4 Ventral view of the four principal motor decussations of the brainstem. Pathways are numbered in accordance with their sequence of activation in voluntary movements: **(1)** corticopontocerebellar; **(2)** dentatothalamocortical; **(3)** corticospinal; **(4)** olivocerebellar. Also shown is the rubroolivary connection.

The same arrangement holds good for the brainstem. The descending motor fibres terminating in the brainstem are *corticobulbar*. As shown in Figure 17.3, the motor nuclei receiving bilateral corticobulbar input are the motor nuclei of cranial nerve V, the motor nuclei of cranial nerve VII for the upper part of the face, and the nucleus ambiguus (cranial nerves IX and X). Note that the motor nucleus receiving totally crossed corticobulbar input is the motor nucleus of cranial nerve VII for the lower face, whereas the corticobulbar input to motor nucleus of hypoglossal nerve is more crossed than uncrossed. The corticobulbar input is entirely contralateral to the somatic sensory nuclei.

Absent from this figure are the three pairs of motor ocular nuclei. Why? Because these nuclei do not receive a direct corticobulbar supply. Instead their predominantly contralateral supply synapses on adjacent cell groups known as *gaze centres* that have the function of synchronising conjugate (conjoint parallel) movements of the eyes.

For a basic understanding of neural relationships in the brainstem, it is also essential to appreciate hemisphere linkages to the inferior olivary nucleus and to the cerebellum (Figure 17.4).

The general layout of the **reticular formation** (Figure 17.5) is borrowed from a figure in Chapter 24 devoted to this topic. It may be consulted when reading under this heading in successive descriptions.

Figure 17.6 depicts the main components of the **medial longitudinal fasciculus (MLF)**. This fibre bundle extends the entire length of the brainstem, changing its fibre composition at different levels. This figure, too, may be consulted during study of the brainstem sections to be described, following inspection of the C1 segment of the spinal cord.

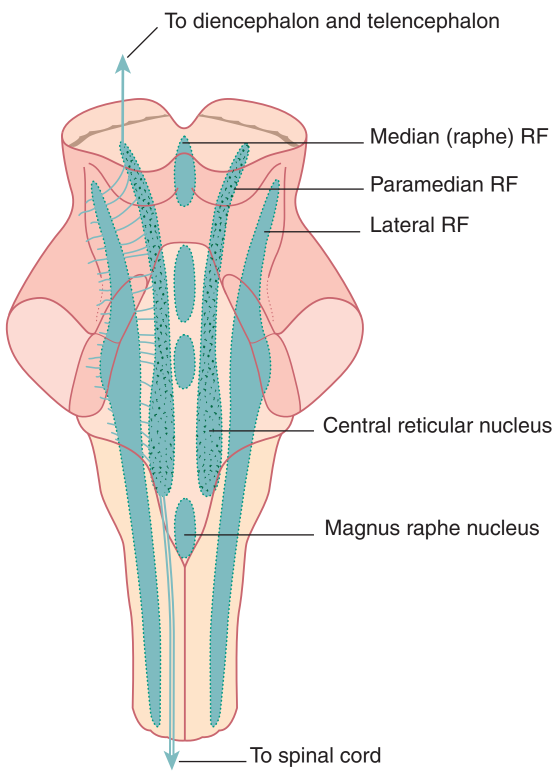

FIGURE 17.5 Layout of the reticular formation (RF).

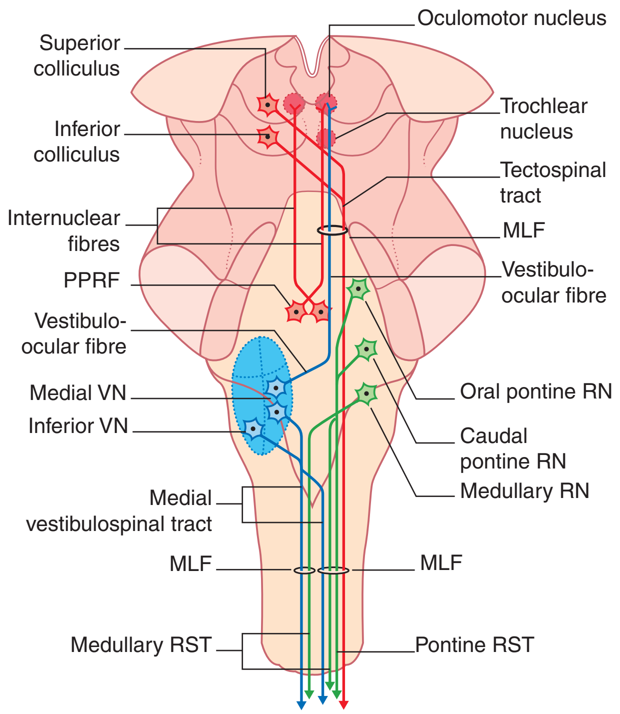

FIGURE 17.6 Main fibre composition of the medial longitudinal fasciculus (MLF). PPRF, paramedian pontine reticular formation; RN, reticular nucleus; RST, reticulospinal tract; VN, vestibular nucleus.

Study guide

The presentation departs from the traditional method, which is to describe photographs or diagrams at successive levels in ascending order without highlights. In the present approach:

1. The various nuclei and pathways are highlighted and labelled on the side having primary affiliation with the right cerebral hemisphere.
2. The nuclei and pathways are colour coded by systems, for example red for motor, blue for sensory, and green for connections of the cerebellum and reticular formation.
3. Highlighting together with colour coding makes it possible to study individual systems in vertical, 'multiple window' mode. The descriptive text related to the brainstem sections enables a logical sequence of study whereby afferent pathways can be followed from below upwards to the thalamic level (commencing with Figure 17.10) and efferent pathways can be followed from above downwards (commencing with Figure 17.19). It must be emphasised that, following study in the vertical mode, a horizontal approach must be undertaken, with the location of the various systems to be identified at each level. This is because occlusion of a small artery of supply to the brainstem may affect function in a patch that may include several distinct nuclei or pathways.

At each level, miniature replicas of the diagrams in Figure 17.7 are inserted to assist left–right orientation.

Special note: Readers unfamiliar with the internal anatomy of the brainstem may be disconcerted by the amount of new information contained in the series of sections to be described. It may be reassuring to know that *all* the information will come up again in later chapters. Therefore a sensible approach could be to undertake an initial browse through the sections and to recheck the location of individual items during later reading.

Overview of three pathways in the brainstem

Figure 17.8 shows the *dorsal column–medial lemniscal* and *anterolateral pathways* already described in Chapter 15. Recall that the latter comprises

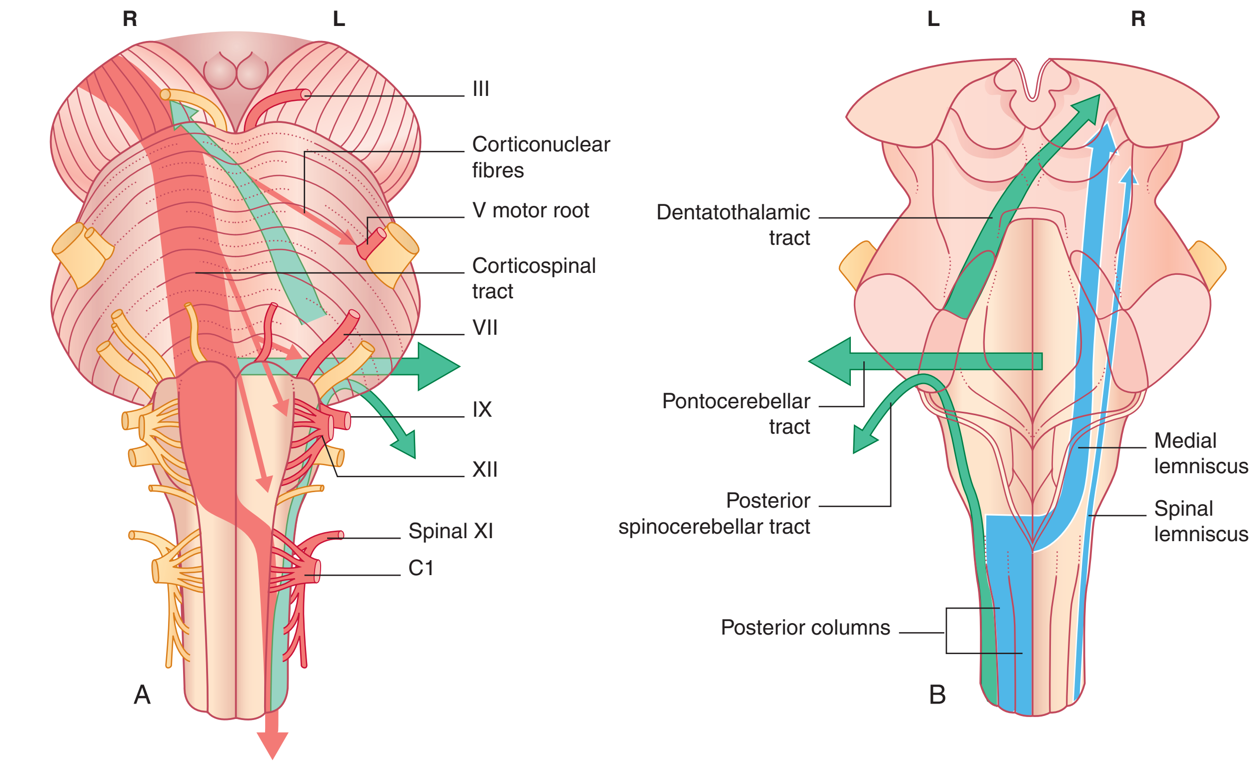

FIGURE 17.7 **(A)** Ventral and **(B)** dorsal view of brainstem, showing disposition of some major pathways.

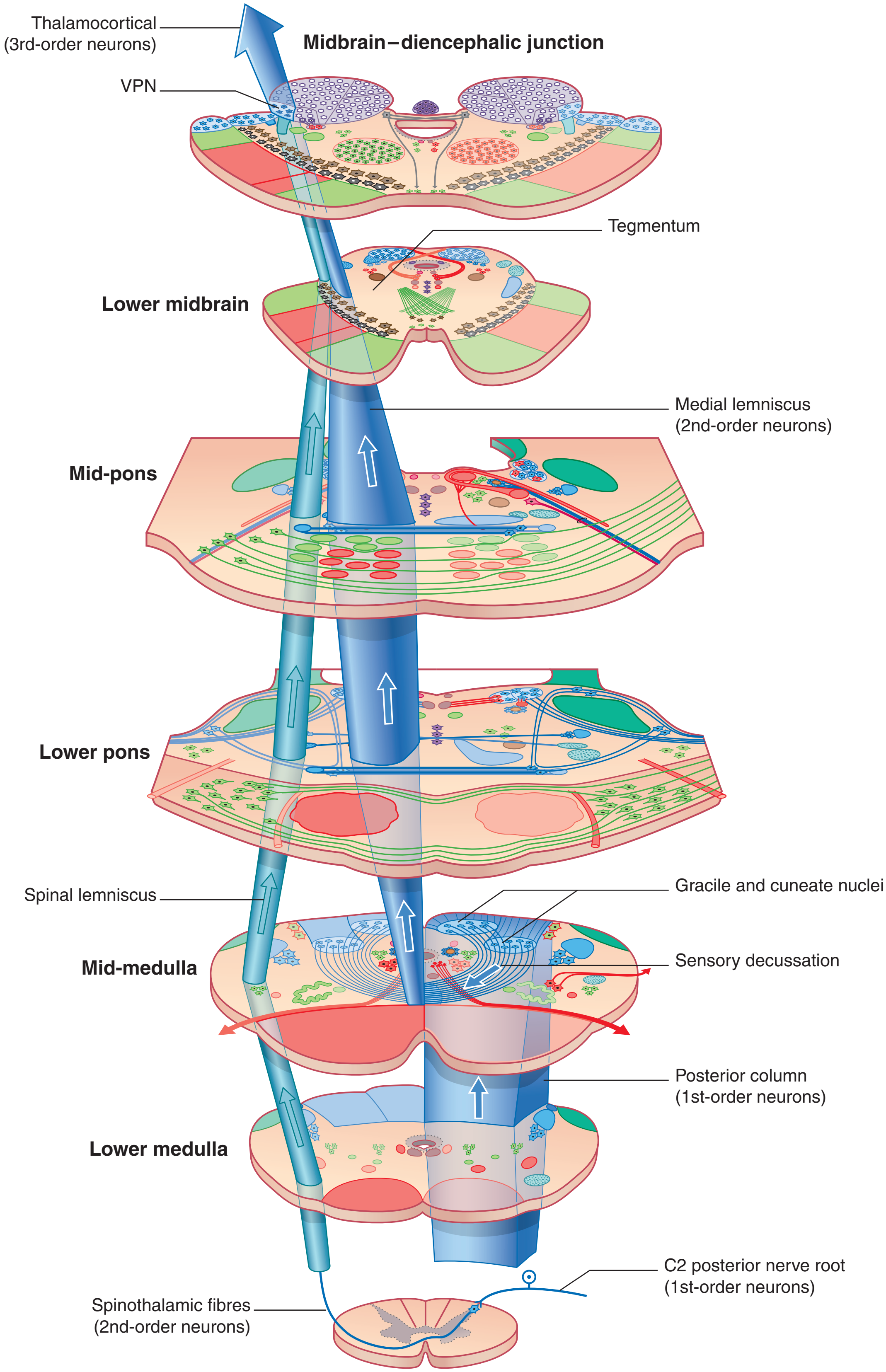

FIGURE 17.8 Dorsal column–medial lemniscal and anterolateral pathways. VPN, ventral posterior nucleus of the thalamus.

the *neospinothalamic tract* serving pain and temperature and the *reticulospinal tract* serving dull aching pain. This pathway terminates in the reticular nuclei of the brainstem forming the *central tegmental tract*, which terminates in the intralaminar nuclei of the thalamus. The third component of the anterolateral system is the *spinotectal tract* that terminates in the midbrain (at the level of the superior colliculus) and is responsible for the coordination of head and eye movements.

The *corticospinal tract*, treated in Chapter 16, is shown in Figure 17.9. Also included are corticobulbar projections to the facial and hypoglossal nuclei.

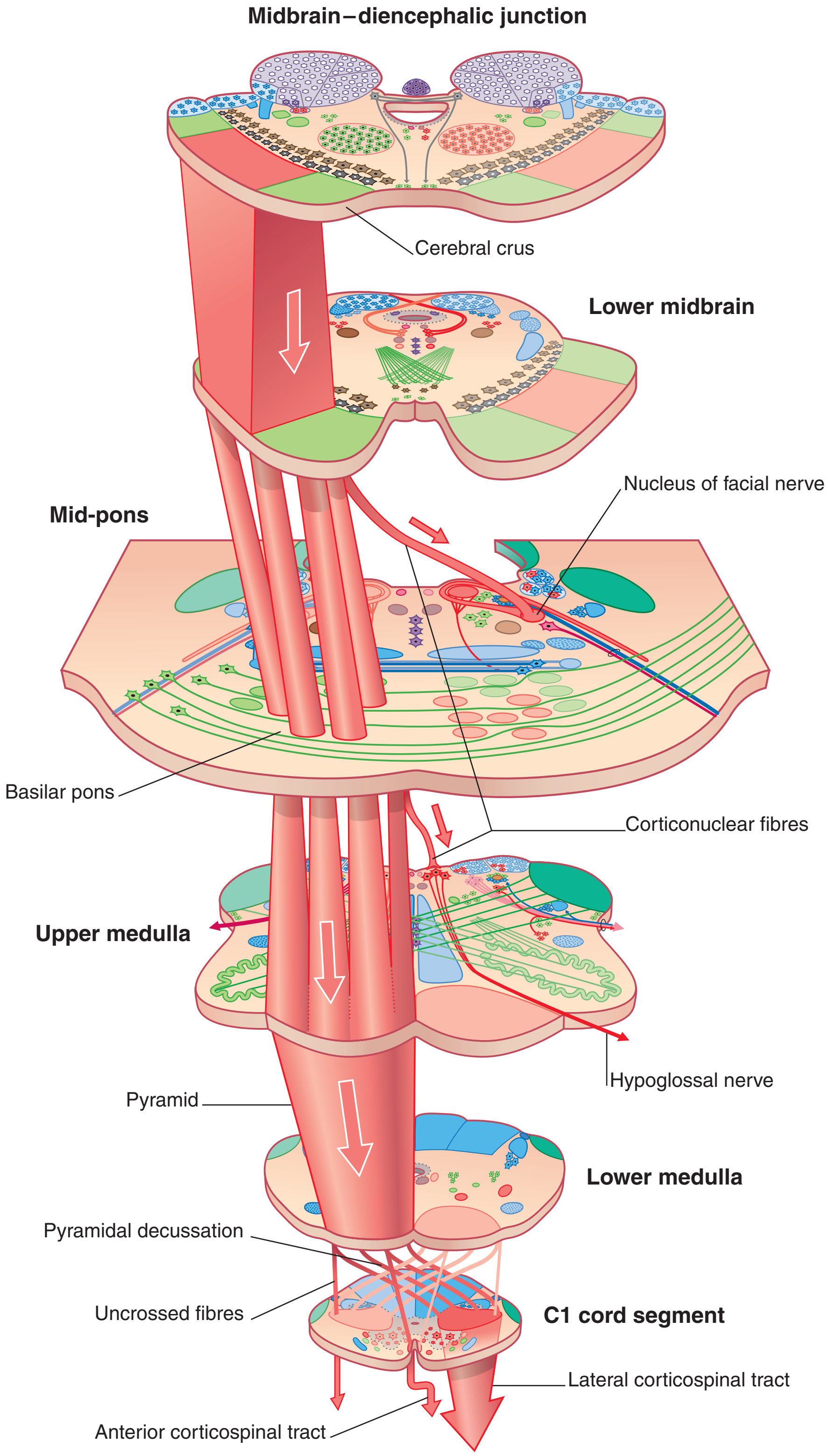

FIGURE 17.9 Corticospinal tract; two corticobulbar projections.

C1 SEGMENT OF THE SPINAL CORD (FIGURE 17.10)

Blue

The *gracile* and *cuneate fasciculi* constitute the dorsal column of the spinal cord on each side. Their axons are ipsilateral central processes of dorsal root ganglion cells whose peripheral processes receive information from the large tactile nerve endings in the skin, including Meissner and Pacini corpuscles, and from neuromuscular spindles and Golgi tendon organs. The fasciculi terminate in the gracile and cuneate nuclei (Figure 17.12).

Unlike the dorsal column, the anterolateral tract contains *crossed* axons. As indicated in Figure 15.10, the second-order neurons traverse the ventral white commissure at all segmental levels before ascending to the thalamus.

The *dorsolateral tract of Lissauer* contains fine first-order sensory fibres that divide and span several cord segments prior to synapsing in the dorsal grey horn.

The *spinal (descending) tract* of the trigeminal nerve contains nociceptive and thermoceptive first-order neurons about to synapse in the dorsal grey horn of segments C2 and C3.

Red

The large red area on the left side of the cord represents the (crossed) *lateral corticospinal tract*. The *ventral corticospinal tract* has not yet crossed.

Anterior motor neurons projecting from the ventral grey horn occupy the ventral root of spinal nerve C1 and the uppermost root of the spinal accessory nerve.

The *lateral vestibulospinal tract* (uncrosssed) descends in the ventral funiculus to activate antigravity muscles on its own side. *The medial vestibulospinal tract* (partly crossed) has emerged from the MLF to activate head-righting reflexes.

Lateral to the ventral grey horn is the autonomic projection from the hypothalamus. Its functions include activation of sacral parasympathetic neurons causing contraction of the bladder and rectum.

Green

The *dorsal spinocerebellar tract* (from the posterior thoracic nucleus) conveys high-speed unconscious proprioception from the ipsilateral trunk and limbs, notably from muscle stretch receptors.

The *pontine reticulospinal tract* is descending ipsilaterally to supply motor neurons innervating antigravity muscles. The *medullary reticulospinal tract* supplies flexor motor neurons.

SPINOMEDULLARY JUNCTION (FIGURE 17.11)

Blue

The *gracile* and *cuneate fasciculi* continue to occupy the dorsal white column, with the *spinal tract and nucleus* of the trigeminal nerve alongside. The position of the *spinal lemniscus* is also unchanged.

Red

The dominant feature in this diagram is the *decussation of the pyramids*. Observe the right pyramid: 80% of its fibres cross the midline by decussating with its opposite numbers, to form the left *lateral corticospinal tract*; 10% enter the ipsilateral *ventral corticospinal tract* which will cross lower down; and 10% remain ipsilateral among the fibres of the right lateral corticospinal tract.

Within the lateral tegmentum is the *lateral vestibulospinal tract*. The red spots in the medial longitudinal fasciculi represent the *medial vestibulospinal tract*, which descends bilaterally within them.

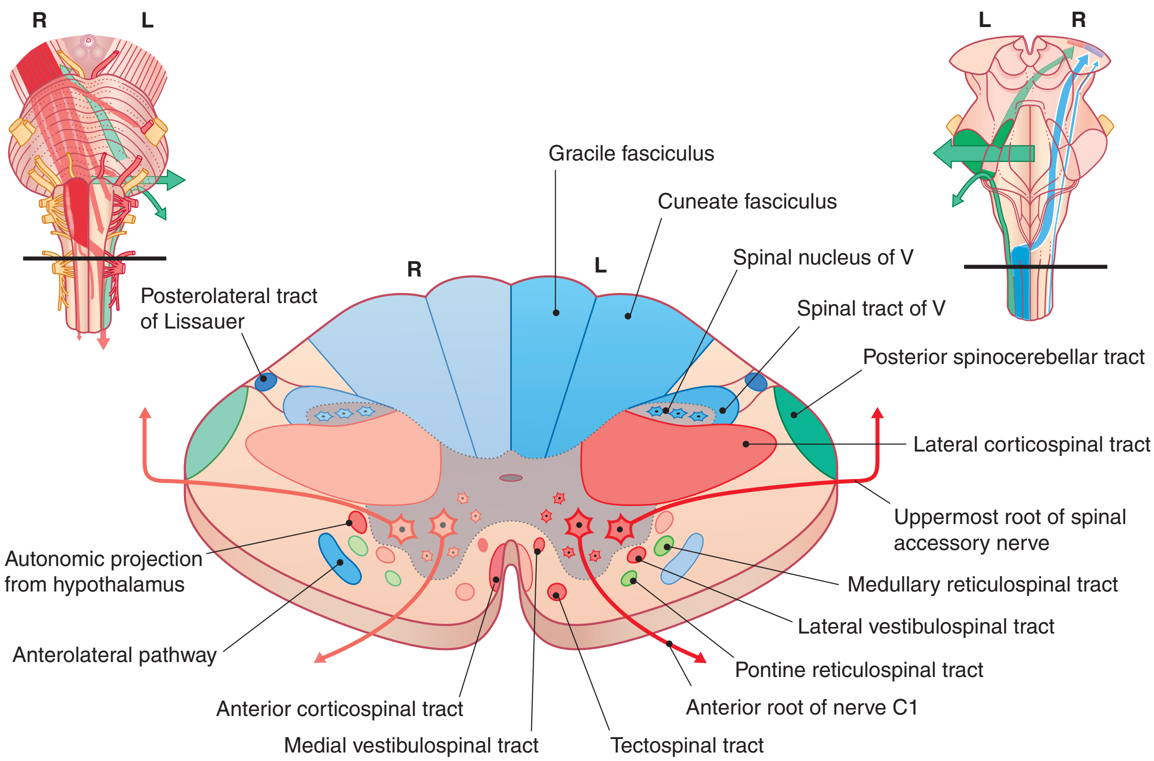

FIGURE 17.10 C1 segment of the spinal cord.

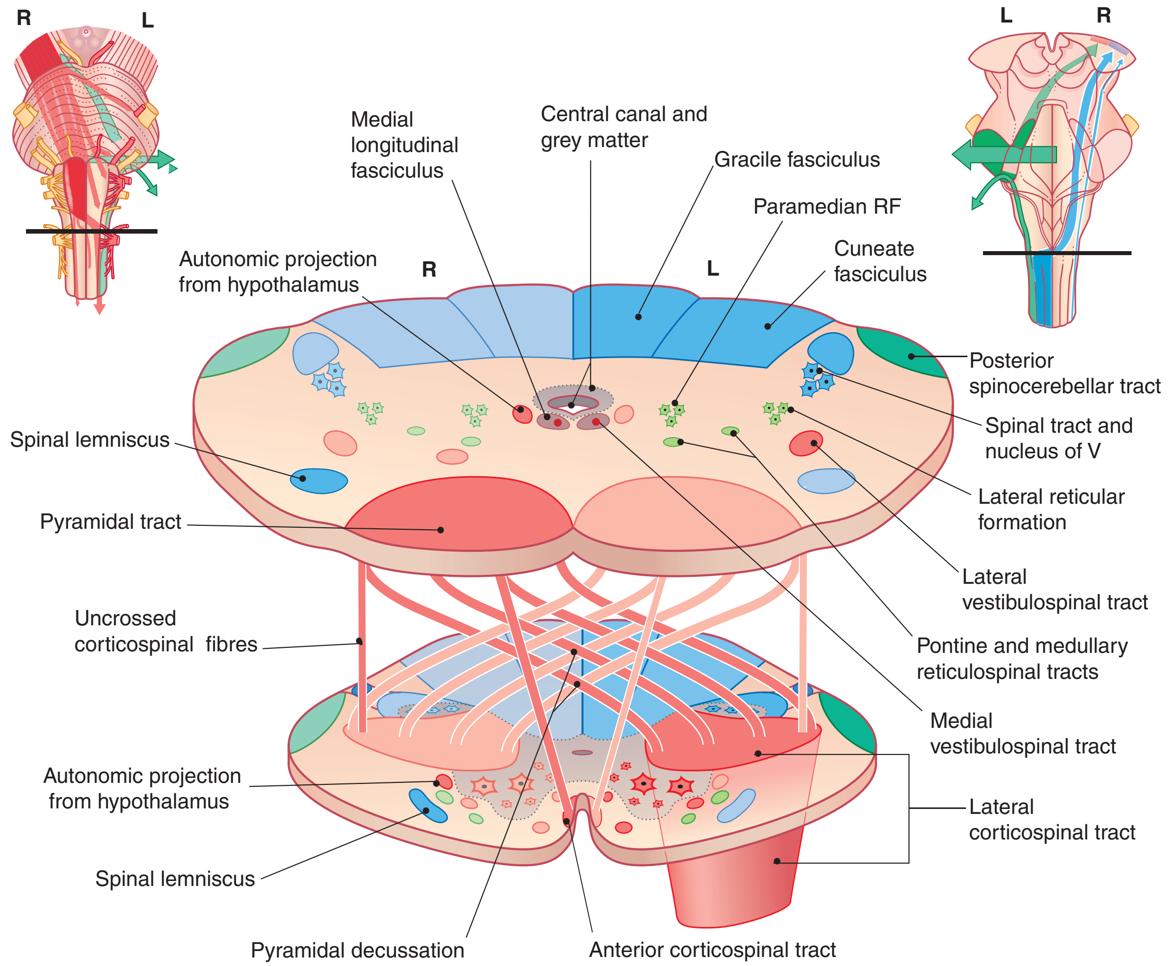

FIGURE 17.11 Spinomedullary junction.

Green

The *dorsal spinocerebellar tract* is nearing its point of departure into the inferior cerebellar peduncle. The *paramedian* and *lateral reticular formation* occupy the tegmentum.

MIDDLE OF THE MEDULLA OBLONGATA (FIGURE 17.12)

Blue

The left dorsal column of the spinal cord ascends to mid-medulla before turning ventrally. The *gracile fasciculus* synapses in the *gracile nucleus*, the cuneate one in the *cuneate nucleus*. Second-order neurons give rise to *internal arcuate fibres,* which cross over in the great *sensory decussation*, then ascend (to the thalamus) as the *medial lemniscus*.

The anterolateral system (ALS) contains the neospinothalamic, spinoreticular, and spinotectal tracts.

The *vestibulospinal tract* is descending from the vestibular nucleus to the spinal cord.

Red

The *pyramid* contains the corticospinal tract prior to the pyramidal decussation; the *hypoglossal nerve* emerges at its lateral edge. Lateral to the XII nucleus is the *dorsal nucleus of vagus nerve*. The *'cranial' accessory nerve* has emerged from the nucleus ambiguus; it will be incorporated into the vagus below the jugular foramen. The *dorsal longitudinal fasciculus (DLF)* contains autonomic fibres descending from the hypothalamus to the spinal cord.

Green

The projections from *inferior* and *accessory olivary nuclei* to the contralateral cerebellar cortex are shown.

The paramedian and lateral reticular formation and the inferior cerebellar peduncle are seen again now.

UPPER PART OF THE MEDULLA OBLONGATA (FIGURE 17.13)

Blue

In the midregion the *medial lemnisci* are continuing their ascent to the thalamus. Laterally, we see the *spinal lemniscus*, the *spinal tract and nucleus of the trigeminal nerve*, the *solitary tract and nucleus* (S.t.n. in Figure 17.15) and the *medial and lateral nuclei of the vestibular nerve*. Sensory fibres of the glossopharyngeal nerve synapse in the *spinal nucleus of the trigeminal nerve* and in the *solitary nucleus.*

Red

The *pyramids* are in the same position as before. On the anatomic right side, the *vagus nerve* is emerging anterior to the *inferior cerebellar peduncle*. On the left side the motor components of the

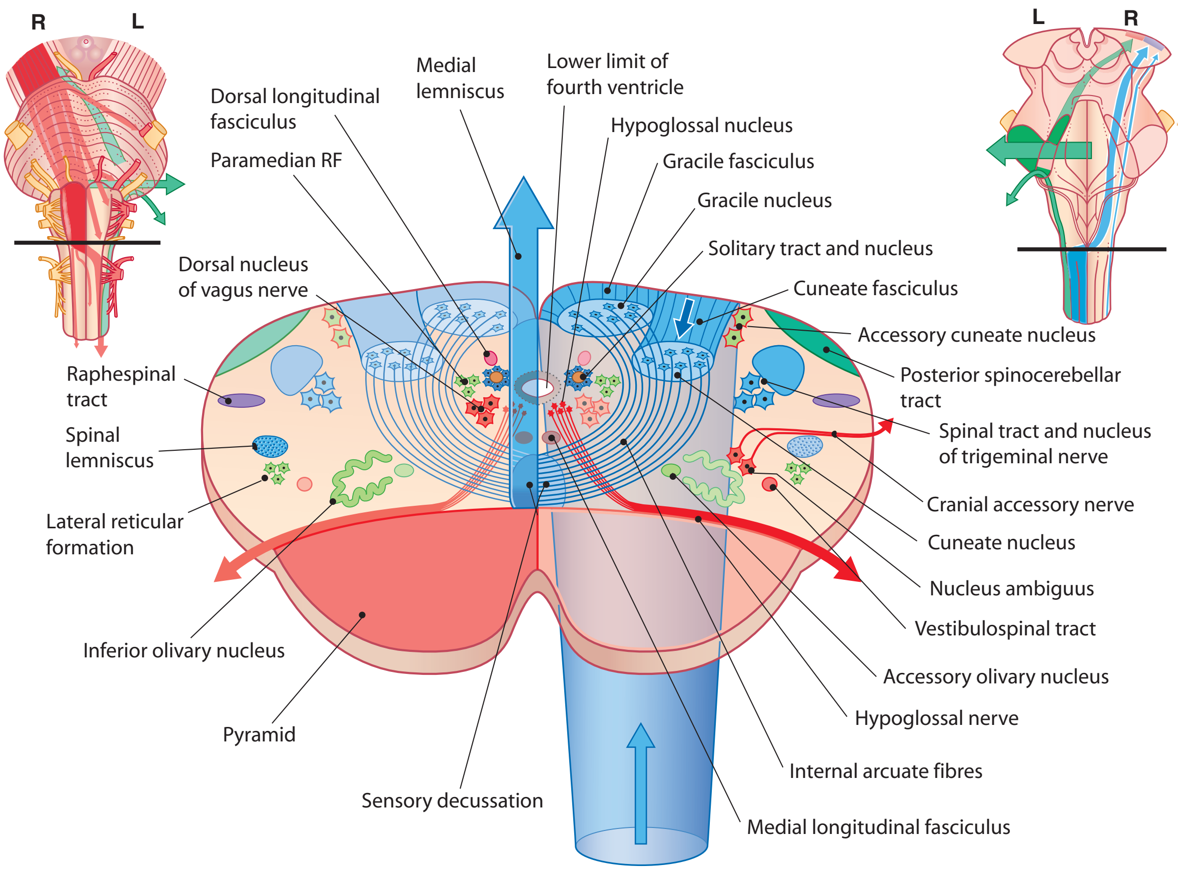

FIGURE 17.12 Middle of the medulla oblongata.

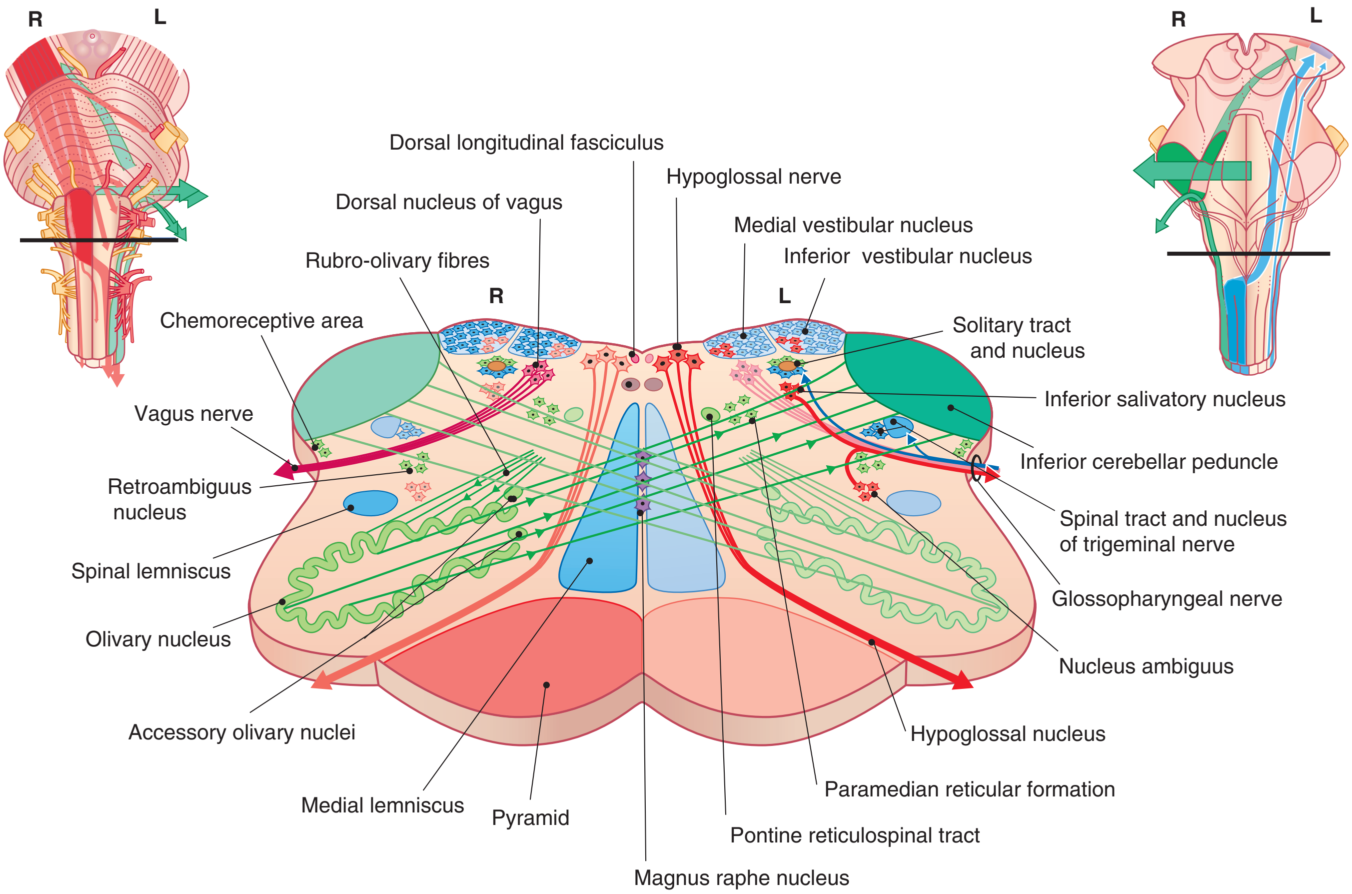

FIGURE 17.13 Upper medulla oblongata.

glossopharyngeal nerve derive from the *inferior salivatory nucleus* and the *nucleus ambiguus*.

Green

The *principal* and *accessory olivary nuclei* are sending fibres across to the contralateral inferior cerebellar peduncle. Dorsal to these are the *chemoreceptive area* (sensitive to HCO_3 levels in the cerebrospinal fluid), the *lateral reticular nucleus, pontine reticulospinal tract*, and *paramedian reticular formation*.

Occupying the midline region are the *magnus raphe nucleus* and the *medial* and *dorsal longitudinal fasciculi*.

PONTOMEDULLARY JUNCTION (FIGURE 17.14)

Blue

Previously seen are the medial and spinal lemnisci, also the spinal tract and nucleus of the trigeminal nerve. Newly seen are the *lateral* and *trigeminal lemnisci*. As explained in Chapter 20, the lateral lemniscus is an auditory fibre bundle ascending to the inferior colliculus, having crossed in the *trapezoid body* from the *superior olivary nucleus*. This nucleus is fed by auditory information from the *dorsal* and *ventral cochlear nuclei*, where the cochlear nerve terminates.

Red

Reflex balance pathways here are the *medial* and *lateral vestibulospinal tracts (VST in the figure)*. The medial tract descends to the spinal cord within the *MLF*.

Also seen are the *corticospinal tract* and the emerging *abducens* and *facial nerves*.

The *DLF* contains autonomic fibres descending to the spinal cord.

Green

At top are the *superior cerebellar peduncles*, which (Chapter 25) project from the dentate nucleus of the cerebellum to the contralateral thalamus. Below these are the *inferior cerebellar peduncles*. More centrally are the *pontine reticulospinal tract* and the *paramedian reticular formation*.

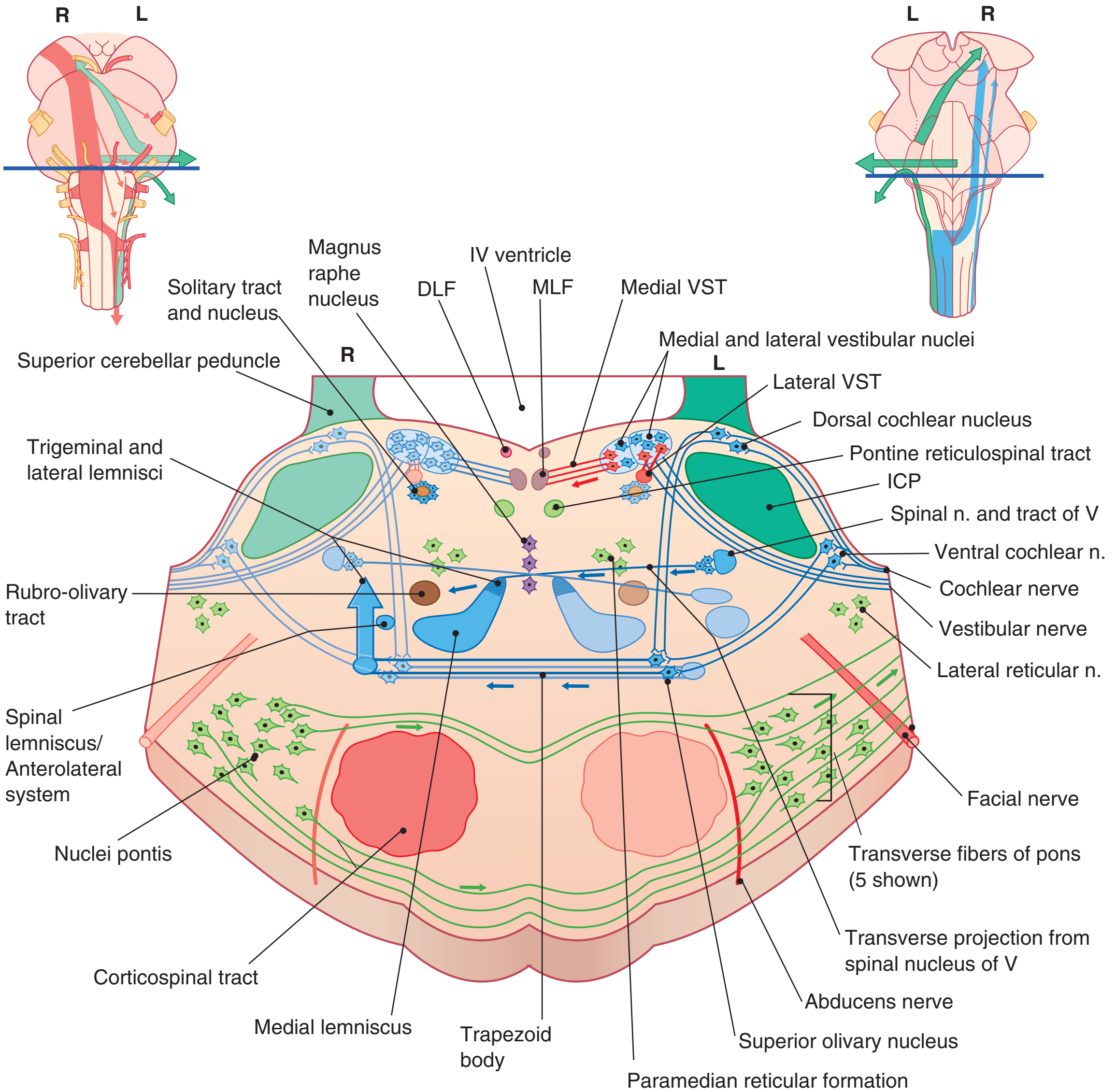

FIGURE 17.14 Pontomedullary junction.

MID-PONS (FIGURE 17.15)

Blue

Medial, lateral, and *trigeminal lemnisci* are progressing towards the thalamus. We have reached the upper end of the *vestibular*, *spinal V,* and *solitary nuclei* and of the *trapezoid body*.

The *nervus intermedius* contains gustatory fibres for the supply of taste buds in the tongue and palate. They terminate centrally in the solitary nucleus.

Red

The *facial nerve* is J-shaped, like a bended knee (genu), where it winds around the nucleus of the *abducens nerve* before piecing the tegmentum, where it is joined by the *nervus intermedius*. This nerve contains parasympathetic secretomotor fibres that will synapse on autonomic ganglia innervating the lacrimal and submandibular glands (among others).

Green

At the top, the arrows indicate imminent intersection of the *superior cerebellar peduncles* in the roof of the fourth ventricle. At a lower level, the *inferior peduncles* are entering the cerebellum.

In the basilar pons, millions of *corticopontine fibres* descend from the cerebral cortex to synapse upon millions of individual neurons collectively called *nuclei pontis*. These give off transverse fibres that separate the corticospinal tracts into bundles, on their way to create the *middle cerebellar peduncle* on the contralateral side.

Beside the abducens is the *pontine gaze centre/paramedian pontine reticular formation*, a node of reticular formation that activates contraction of the lateral rectus muscle in the orbit, thereby causing abduction of the corresponding eyeball.

In the midline the *pontine raphe nucleus* sends serotonergic fibres throughout pons and cerebellum.

UPPER PONS (FIGURE 17.16)

Blue

The *sensory root of the left trigeminal nerve* terminates in the *pontine sensory nucleus*. From here, axons project across the midline and turn upward as the *trigeminal lemniscus*. Three lemnisci previously seen are the *spinal*, *lateral*, and *medial lemnisci*.

The *mesencephalic tract of the trigeminal nerve* (Mes. t. V in the figure) contains processes of unipolar neurons in the midbrain, as explained in Chapter 21.

Red

The *cerulean nucleus*, in the floor of the upper end of the fourth ventricle, is the largest group of noradrenergic neurons in the brain. It distributes fine, beaded axons to all parts of the cerebral and cerebellar hemispheres.

The *motor nucleus of the trigeminal nerve* provides the axons of supply to the masticatory muscles.

Previously seen are the *corticospinal fibre bundles* and the *DLF*.

Green

Next to the superior cerebellar peduncle (SCP in the figure), the *pedunculopontine nucleus* is part of the locomotor centre (Chapter 24).

Previously seen are the corticopontine and pontocerebellar fibres.

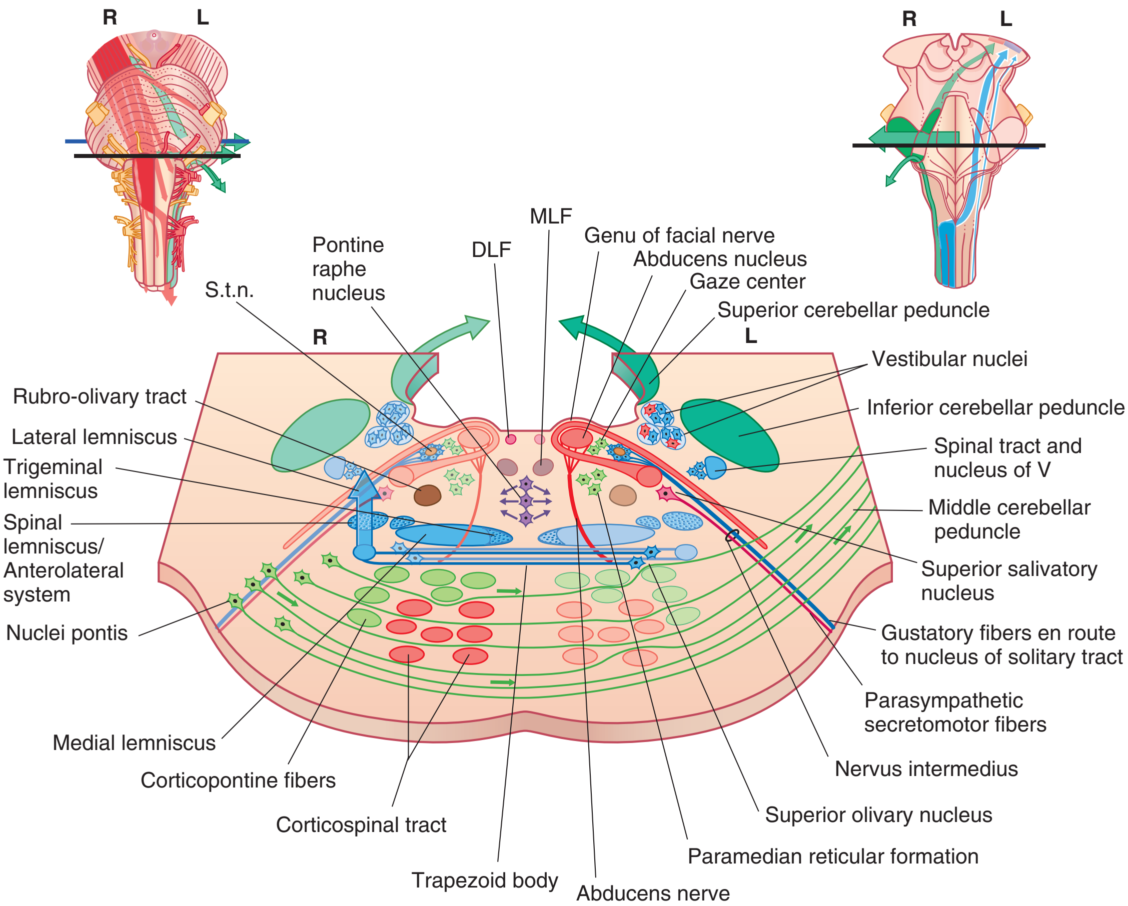

FIGURE 17.15 Mid-pons.

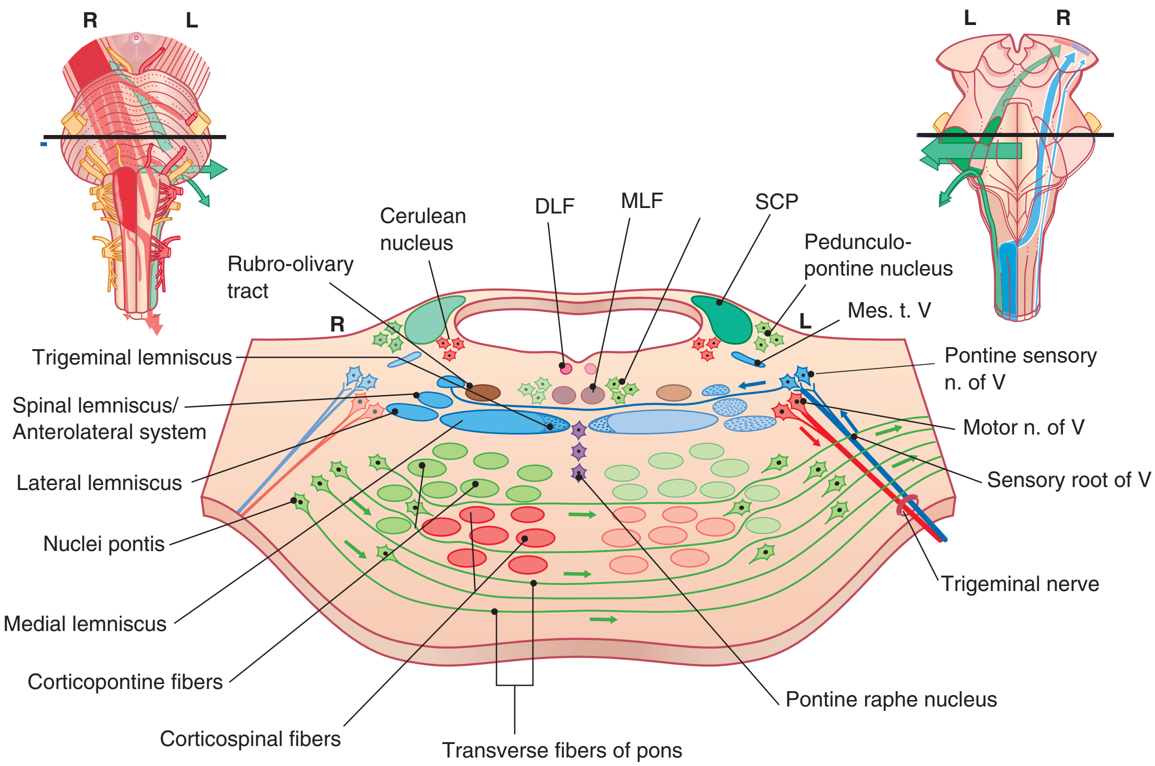

FIGURE 17.16 Upper pons.

LOWER MIDBRAIN (FIGURE 17.17)

Blue

The *medial*, *spinal*, and *trigeminal* (V) *lemnisci* are still ascending, whereas the lateral lemniscus is now on target, synapsing in the inferior colliculus—the lower centre for hearing.

The *mesencephalic nucleus of the trigeminal nerve* (Mes. n. V in the figure) is the *only* unipolar cell group within the central nervous system (CNS). It serves proprioception within the trigeminal area.

Red

The *trochlear nerve* is the *only* cranial nerve to decussate (as shown); also the *only* cranial nerve to emerge from the dorsal surface of the brainstem.

The *DLF* contains autonomic fibres traveling to the spinal cord. The crus of the midbrain contains *corticobulbar* and *corticospinal fibres*; the former activate motor cranial nerve nuclei. The *tectospinal tract* is commencing its descent, having crossed from the contralateral superior colliculi. It operates visuospinal reflexes whereby the head and trunk are turned in the direction of a source of light.

Green

The *fronto-* and *parieto-temporo-occipital pontine fibres* are travelling from the corresponding association areas to reach the ipsilateral nuclei pontis.

Brown/grey

The anterior tegmentum is occupied by *compact* and *reticular* elements of the *substantia nigra*. The compact part, comprising pigmented dopaminergic neurons, is the source of the *nigrostriatal pathway* to the corpus striatum. The nigrostriatal pathway loses both pigment and cells in those unfortunates bound for *Parkinson disease* (Chapter 33). The reticular part contains γ-aminobutyric acid (GABA)ergic neurons.

UPPER MIDBRAIN (FIGURE 17.18)

The four occupants of the crus cerebri and the substantia nigra are in the same relative positions. So too are the midbrain raphe nucleus and the ventral tegmental and interpeduncular nuclei.

Blue

The *medial*, *spinal*, and *trigeminal lemnisci* continue to move dorsally as they near the thalamus. The *spinotectal tract* has emerged from the spinal lemniscus to enter the superior colliculus.

Red

At the top, the two *tectospinal tracts* have emerged from the superior colliculus and have undergone decussation. The spinotectal and tectospinal tracts operate the *spinovisual reflex* whereby the eyes and head turn in the direction of tactile stimuli. The *oculomotor nerves* have pierced the *red nuclei* and *substantia nigra* to reach the *interpeduncular fossa*. The *Edinger–Westphal nucleus* (E-W n. in the figure) sends preganglionic parasympathetic fibres into the nerves; they activate the ciliary ganglion whose postganglionic fibres cause contraction of the pupillary sphincter and the ciliary muscle.

Green

Most *dentatothalamic fibres* travel direct to the contralateral thalamus. A minority synapse in the red nucleus whence *rubro-olivary* fibres are relayed onward within the *central tegmental tract*.

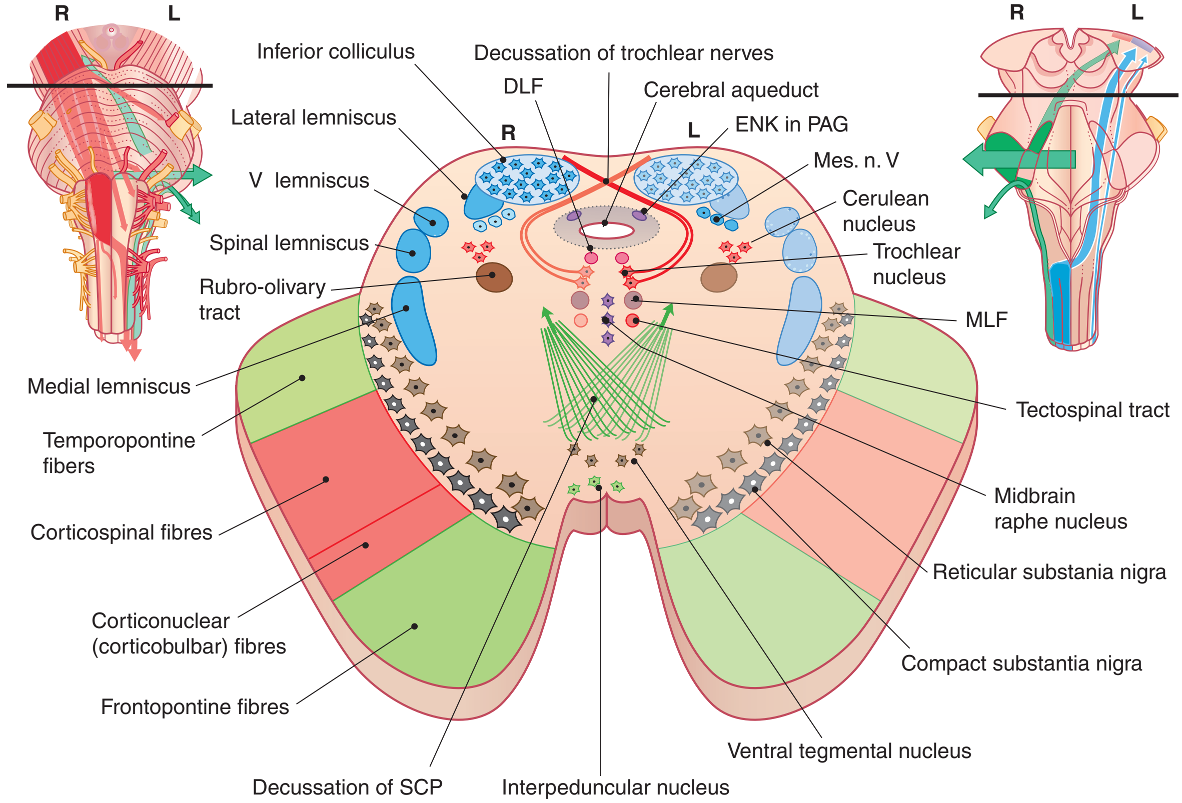

FIGURE 17.17 Lower midbrain.

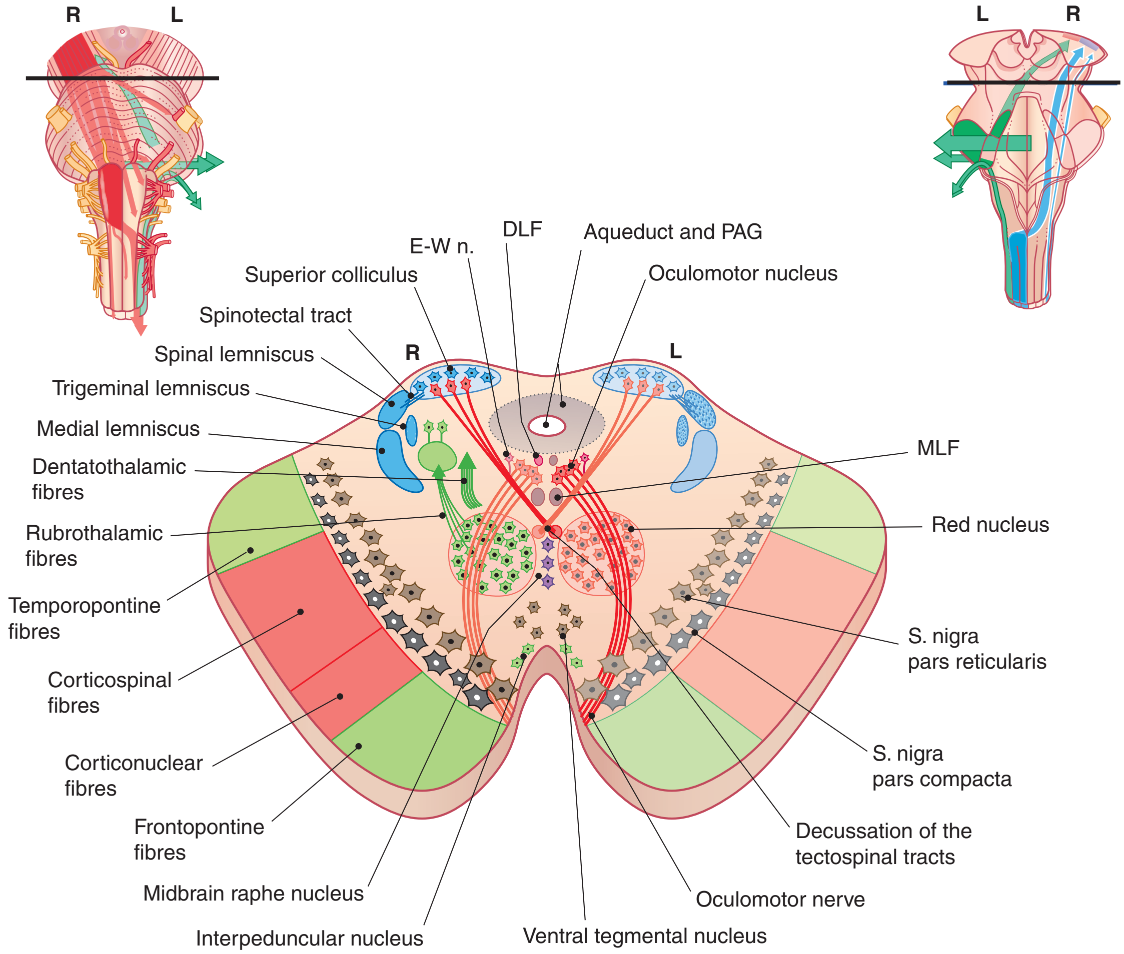

FIGURE 17.18 Upper midbrain.

MIDBRAIN–THALAMIC JUNCTION (FIGURE 17.19)

Blue

Ascending to the ventral posterior nucleus of the thalamus are three lemnisci (*medial, spinal, trigeminal*). Entering the *medial (auditory) geniculate nucleus (MGN)* of thalamus is the *inferior brachium,* which arose in the *inferior colliculus*. The *lateral (visual) geniculate nucleus (LGN)* receives the superior brachium (not seen here).

Red

The *subthalamic nucleus* receives an input from the centromedian nucleus of the thalamus and projects to the lentiform nucleus. It may become overactive in Parkinson disease (see Chapter 33). The red nucleus and the contents of the crus cerebri are unchanged.

Green

In the dorsal tegmentum the *pretectal nucleus* belongs to the visual system. It receives an input from the optic tract and projects to both Edinger–Westphal nuclei, giving rise to bilateral pupillary constriction when a light is shone into one eye (Chapter 23).

Near the midline are the centres for upward and downward gaze. Rarely, a *pinealoma* (pineal gland tumour) may signal its presence by causing *paralysis of upward gaze*.

The superior cerebellar peduncle is aiming for the ventral lateral nucleus of the thalamus, which lies anterior to the ventral posterior nucleus. From there, a final projection will reach the motor cortex and will coordinate ongoing movements.

Green

The *habenular nuclei* are connected across the midline and project via the *fasciculus retroflexus* to the *interpeduncular nucleus*, which participates in the sleep–wake cycle (Chapter 34).

ORIENTATION OF BRAINSTEM SLICES IN MAGNETIC RESONANCE IMAGES (FIGURE 17.20)

Figure 17.20 shows brainstem slices in magnetic resonance images. Their orientation is the opposite of those in the preceding sections. In photographs and drawings the convention is to represent anterior structures below. As already mentioned in Chapter 2, in magnetic resonance imaging scans, anterior structures are represented above.

Epilogue

Figure 17.21 offers an unlabelled overview of the brainstem sections. Gentle skimmers may opt to photocopy lightly and to crayon pathways.

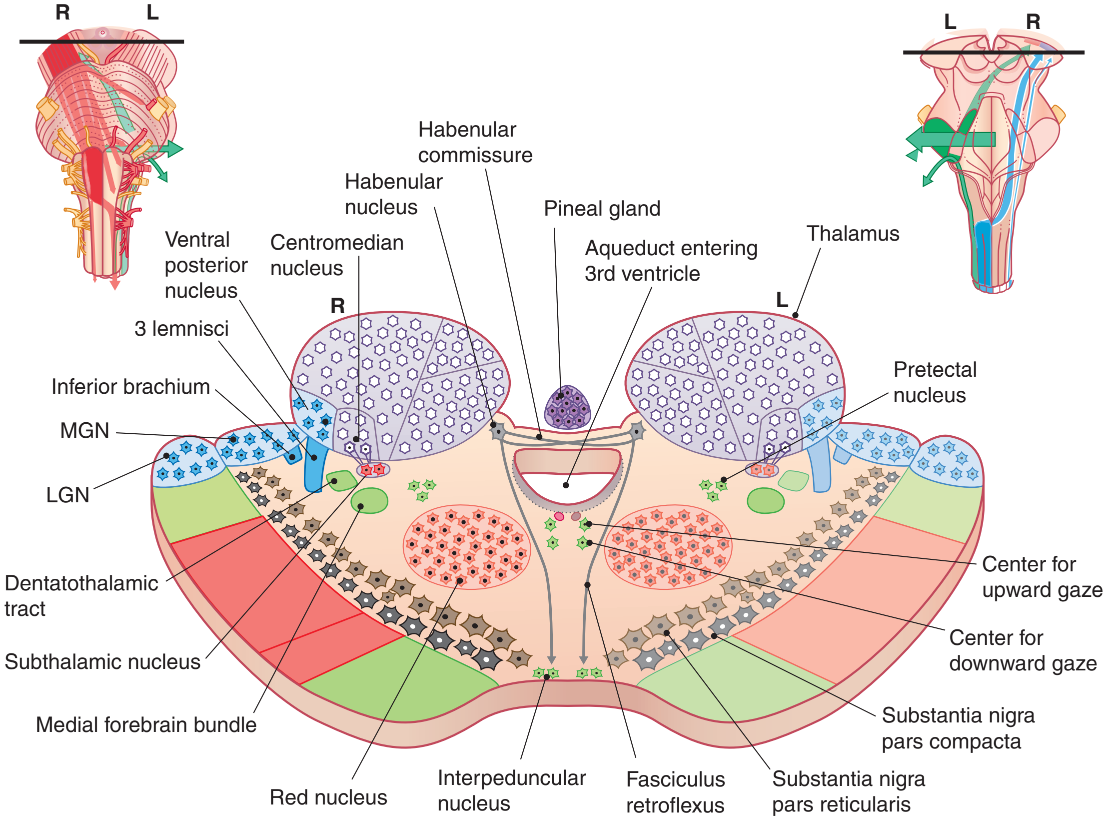

FIGURE 17.19 Midbrain–thalamic junction.

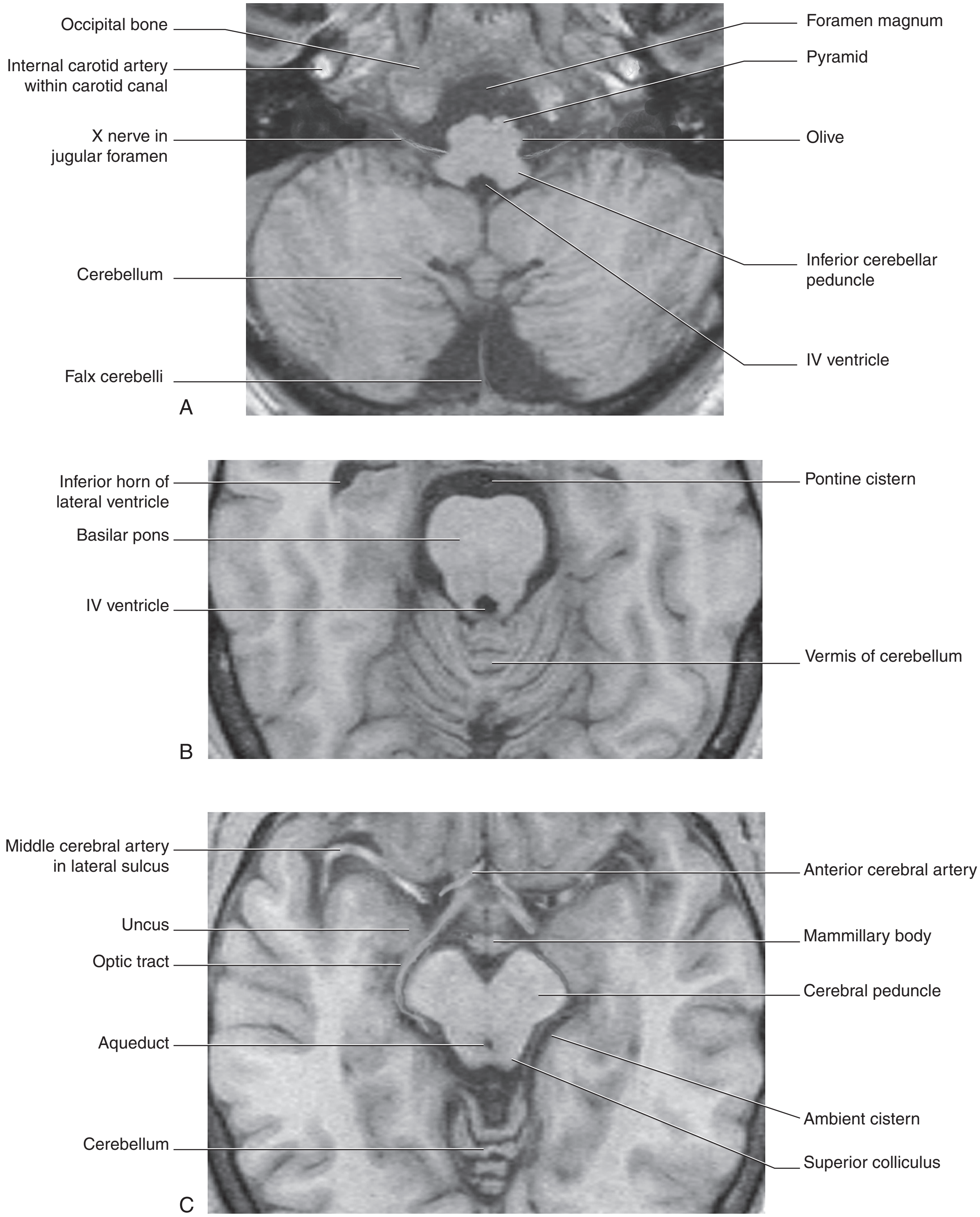

FIGURE 17.20 Magnetic resonance images of **(A)** medulla oblongata, **(B)** pons, and **(C)** midbrain in the standard radiologic orientation. (From a series kindly provided by Professor J. Paul Finn, Director, Magnetic Resonance Research, Department of Radiology, David Geffen School of Medicine at UCLA, California.)

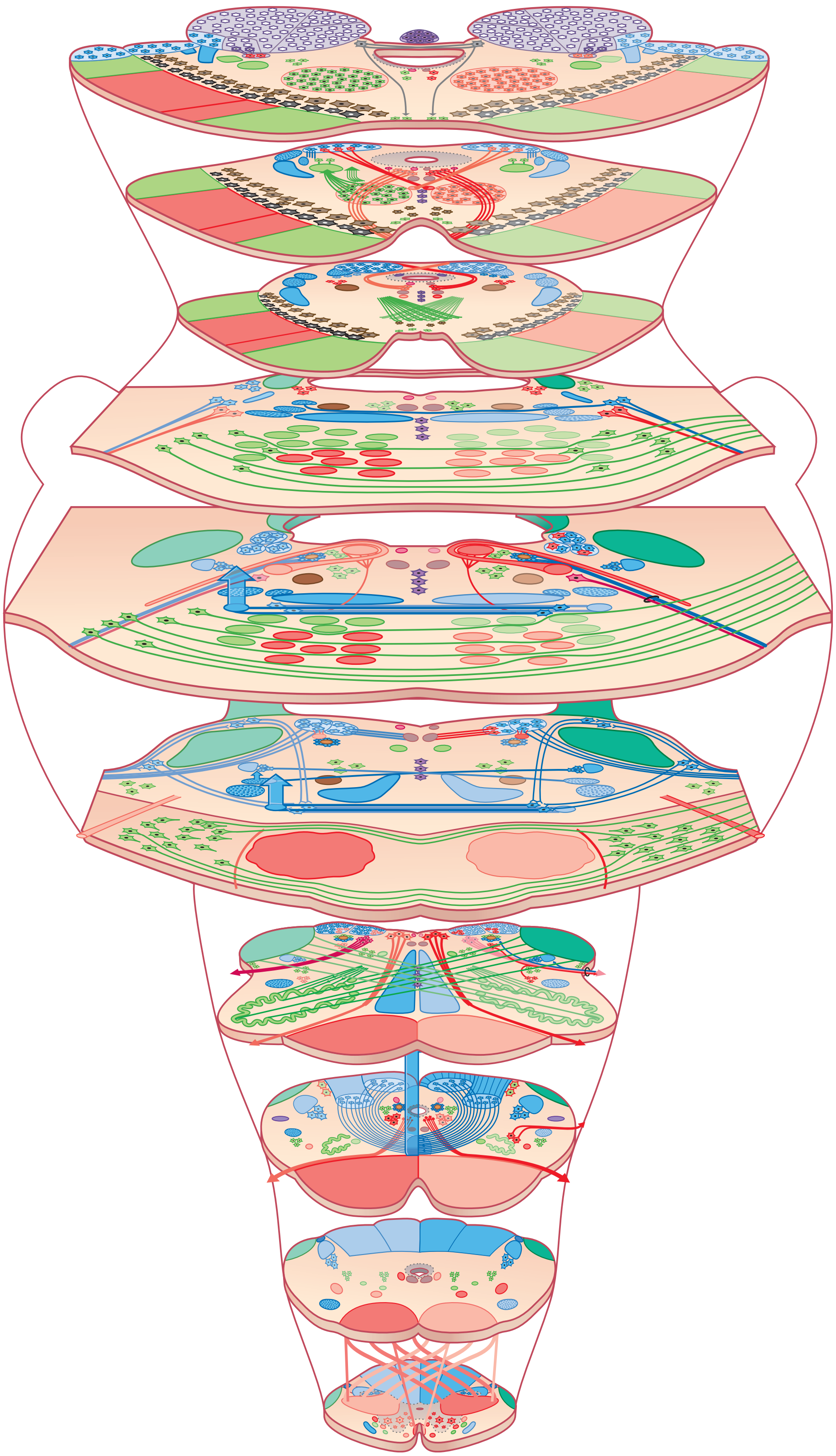

FIGURE 17.21 Brainstem review.

CORE INFORMATION

Cell columns

Cranial nerve cell columns and their representations are as follows.

- *GSE,* represented in the medulla by the hypoglossal nucleus, in the pons by the abducens nucleus, and in the midbrain by the oculomotor and trochlear nuclei.
- *SVE*, supplying muscles of branchial arch origin, represented in the medulla by the nucleus ambiguus and in the pons by trigeminal and facial motor nuclei.
- *GVE*, represented in the medulla by dorsal motor nucleus of Vagus, in the medulla and pons by the inferior and superior salivatory nucleus GVE represented in the medulla by dorsal motor nucleus of Vagus, in the medulla and pons by the inferior and superior salivatory nucleus **and in the midbrain by the Edinger Westphal nucleus**.
- *GVA*, represented in the medulla by the inferior solitary nucleus.
- *SVA*, represented in the pons by the superior solitary nucleus.
- *GSA*, represented by trigeminal sensory nuclei: spinal in the medulla, principal sensory in the pons, and mesencephalic in the midbrain.
- *SSA*, represented at the pontomedullary junction by the cochlear and vestibular nuclei.

Ascending pathways

The gracile and cuneate nuclei send internal arcuate fibres across the midline to form the medial lemniscus, which goes through the pons and midbrain to reach the thalamus. The spinal trigeminal nucleus sends fibres across the midline to form the trigeminothalamic tract. The dorsal spinocerebellar and cuneocerebellar tracts send their fibres into the ipsilateral inferior cerebellar peduncle, where they mingle with olivocerebellar fibres crossing from the inferior and accessory olivary nuclei. The (crossed) ventral spinocerebellar tract enters the superior cerebellar peduncle; its fibres cross a second time within the cerebellar white matter.

- The spinal lemniscus is formed of the ventral and lateral spinothalamic tracts. It is accompanied first by trigeminothalamic fibres, later by the lateral lemniscus and by fibres crossing from the principal trigeminal nucleus completing the trigeminal lemniscus.
- The cochlear nuclei project fibres across the trapezoid body to form the lateral lemniscus, which ascends to the inferior colliculus. Some fibres synapse instead in a superior olivary nuclear relay to the ipsilateral inferior colliculus. Third-order neurons of the inferior colliculus project via the inferior brachium to the medial geniculate body. The medial and superior vestibular nuclei send fibres to the oculomotor nucleus to execute the vestibuloocular reflex.
- The upper part of the central tegmental tract contains fibres of the ascending reticular activating system.
- In the ventral tegmentum of the midbrain are the pigmented (compact) substantia nigra giving rise to the nigrostriatal pathway and the ventral tegmental nucleus giving rise to the mesocortical and mesolimbic pathways. The nonpigmented (reticular) nigral neurons are inhibitory.

Descending pathways other than reticulospinal

Corticobulbar fibres from motor areas of the cerebral cortex are distributed preferentially to contralateral motor cranial nerve nuclei excepting the ocular motor slaves of gaze centres. Corticobulbar fibres from sensory areas synapse in the contralateral trigeminal and dorsal column nuclei and dorsal grey horn of spinal cord.

- Prior to the initiation of a voluntary movement on the left side of the body, the left cerebellar hemisphere is notified by discharges from association areas of the right cerebral cortex, along the corticopontocerebellar pathway. The left cerebellum responds via the dentatothalamocortical pathway, to the right primary motor cortex. Then the right pyramidal tract discharges and on its way down notifies the cerebellum a second time by activating the right red nucleus, which in turn activates the right olivocerebellar tract.
- Corticospinal fibres pass through the middle three fifths of the cerebral crus/peduncle and through the basilar pons (where they are segregated into bundles by transverse fibres), finally creating the pyramid of the medulla before four fifths enter the pyramidal decussation.
- The lateral vestibular nucleus gives rise to the lateral vestibulospinal tract that has an antigravity function. The medial and inferior vestibular nuclei give rise to the medial vestibulospinal tract involved in head-righting reflexes. The tectospinal tract belongs to the spinovisual reflex arc. The DLF contains ipsilateral central autonomic fibres.
- A sleep-related pathway from the septal area reaches the interpeduncular nucleus by way of the habenular nucleus and fasciculus retroflexus.

Reticular formation

In the uppermost midbrain are the upward and downward gaze centres. (The lateral gaze centres adjoin the abducens nucleus in the pons.) The midbrain also contains an upgoing 'arousal' projection from the cuneiform nucleus, a downgoing pain-suppressant projection from the periaqueductal grey matter, and a locomotor generator, the pedunculopontine nucleus.

The pons contains the noradrenergic, cerulean nucleus, also the oral and caudal pontine reticular nuclei, which send ipsilateral pontine reticulospinal tracts to extensor motor neurons. The medullary reticulospinal tract is partly crossed and supplies flexor motor neurons. Three respiratory reticular nuclei also occupy the medulla.

SUGGESTED REFERENCES

(Literature references to individual brainstem nuclei and pathways are to be found in the relevant chapters.)

Kautcherov Y, Huang X-F, Halliday G, et al. Organization of human brainstem nuclei. In: Paxinos G, Mai JK, eds. *The human nervous system*. ed 2. Amsterdam: Elsevier; 2004:267–320.

Noback CR, et al. *The human nervous system: structure and function*. Baltimore: Williams & Wilkins; 1996.