Chapter 1

Figure 1.1 ● The brain, spinal cord, spinal nerves, askull as well as the spinal processes of the vertebrae have been removed and that the dura mater and the arachnoid have been opened up so that the spinal cord may be viewed in its entire length.

Figure 1.2 ● The spinal cord, its meninges, spinal nerves, and sympathetic chain ganglia.

Figure 1.3 ● Diagram demonstrating the difference between autonomic innervation (top) and somatic motor innervation (bottom). Observe that two neurons are present in the autonomic supply, whereas a single motoneuron is present in the somatic motor system.

Chapter 2

Figure 2.1 ● The early development of a human embryo. Fertilization, the fusion of the haploid sperm nucleus with the ovum's haploid nucleus, results in the formation of a diploid cell, known as a zygote. As the zygote undergoes mitosis, a solid cluster of cells is formed, the morula. Continued cell division and rearrangement of the newly formed cells results in the formation of a hollow sphere of cells, the blastocyst, whose cells form the bilaminar germ disc and later the trilaminar germ disc.

Figure 2.2 ● (A) The notochord is responsible for inducing the overlying ectodermal cells to form the neural plate. (B, C) As the embryo continues its development, it enters the stage of neurulation, the process whereby the forming nervous system is brought into the body by the formation of an intermediary neural groove, and finally a neural tube, the precursor of the brain and spinal cord. (D) Note that the neural crest, initially the lateral aspect of the neural plate, becomes separated as the neural tube is formed. Cells of the neural crest give rise to all of the ganglia of the peripheral nervous system as well as to numerous additional structures of the developing embryo.

Figure 2.3 ● Cross-section through a developing human embryo during the process of neurulation. Note the presence of somites, gut, and intraembryonic coelom (body cavity). It is interesting to realize that the precursors of many of the future organ systems, such as the digestive, respiratory, urogenital, musculoskeletal, and nervous systems are being established at this early stage of development.

Figure 2.4 ● Neuroepithelial cells are long cells that initially extend from the pial (marginal) to ependymal surface of the neural tube. As they enter the cell cycle to form new cells, their nuclei migrate along the length of the cell. G_1 phase: the nucleus is in the vicinity of the ventricular surface and begins to migrate to the pial surface. S phase: the nucleus is in the pial surface and at the end of the S phase the nucleus begins its return to the ventricular surface. G_2 phase: the nucleus reaches the ventricular surface and the cell begins to shorten. Mitosis (M phase): the cell divides to give rise to two daughter cells in the ventricular zone.

Figure 2.5 ● The origin of the developing cells of the CNS. Note that all of the cells are derived from the original neural tube, with the notable exception of the microglial cells, which are phagocytes of the CNS and originate from mesenchymal cells. Ependymal cells will line the ventricles of the brain as well as the central canal of the spinal cord; they also participate in the formation of the choroid plexus. Glioblasts will give rise to macroglia, namely the protoplasmic and fibrous astrocytes, as well as to oligodendrocytes; these cells are supporting cells of the CNS and, in the case of oligodendroglia, form myelin sheaths of CNS neurons. Neuroblasts are responsible for the formation of the neurons of the CNS.

Figure 2.6 ● Three-dimensional representation of the human brain (left) and its longitudinal section (right; as if the brain were stretched out) at 6 and 27 mm of development. Note that the three primary brain divisions of the 6 mm embryo give rise to the five divisions of the 27 mm embryo.

Figure 2.7 ● Diagrams of the developing nervous system. (A) Longitudinal section of the brain and spinal cord of an 11 mm embryo. (B) Transverse section of the myelencephalon of an early embryo depicting the alar and basal plates. The arrows indicate the migration of cells from the alar plates to form the future olivary nuclei. (C) Transverse section of a later stage of the myelencephalon depicting the development of nuclei from the alar and basal plates.

Figure 2.8 ● The developing cerebellum: (A, C) longitudinal sections at 6 and 17 weeks, respectively; (B, D) cellular morphology of the developing cerebellum at 6 weeks and shortly after birth. At 11 weeks the cerebellar plate forms and even Purkinje cell precursors are evident. By the twelfth week the right and left cerebellar hemispheres may be observed, separated from each other by the future vermis. By the seventeenth week of development, folia are apparent and the primary fissure is clearly recognizable.

Figure 2.9 ● Development of the pituitary gland (hypophysis). Sagittal section of a 5-week-old embryo displaying the floor of the diencephalon with the beginning of the infundibulum and the roof of the stomadeum, showing its outpocketing, known as Rathke's pouch. (A) By the seventh week of development, Rathke's pouch contacts the infundibulum. (B) Around the ninth week of development, Rathke's pouch loses contact with the stomadeum. (C) Around the tenth week of development, cells of Rathke's pouch proliferate to form the adenohypophysis. (D) The formed pituitary.

Figure 2.10 ● Development of the eye begins with the outgrowth of the diencephalon, known as the optic vesicle, around the time that the embryo is 4.5 mm long from crown to rump. (A) The optic vesicle induces the ectoderm to form the lens placode. (B) By the time the embryo is 5.5 mm long, the optic vesicle invaginates to form the optic cup and the lens placode differentiates to form the lens pit, which at this point is wide open to the outside. (C) The lens pit begins to form the lens vesicle around the time the embryo is 7.5 mm long and the optic cup forms a two-layered structure, the neural and pigment layers. The optic stalk, which will form the optic nerve, is also being established.

Chapter 3

Figure 3.1 ● Diagram of a multipolar neuron. Note that the processes of other neurons make synaptic contacts with it. Synapses may be formed, as illustrated, with the soma or with the dendrites, although other types of synapses also occur.

Figure 3.2 ● Section of a multipolar neuron displaying a messenger RNA, transcribed from the DNA, leaving the nucleus, picking up ribosomes to form a polysome and proceeding to the rough endoplasmic reticulum (RER). On the surface of the RER the mRNA is translated and proteins, destined to be packaged into vesicles, are synthesized and funneled into the lumen of the RER.

Figure 3.3 ● Synapses along a dendrite. Note that one of the axon terminals (terminal boutons, end-feet) has an axon terminal impinging on it, probably acting in an inhibitory capacity. (Modified from Williams, PL, ed. (1998) *Gray's Anatomy*, 38th edn. Churchill Livingstone, London; fig. 7.19b.)

Figure 3.4 ● An axon terminal (terminal bouton) forming a synapse. Note that the synaptic vesicles are in close relationship with the docking complexes of the presynaptic membrane. The axon terminal also houses mitochondria and endosomes.

Figure 3.5 ● Synaptic vesicles are held in reserve by docking complexes near the active sites of the presynaptic membrane. (A) Voltage-gated calcium channels of the presynaptic membrane are closed and the synaptic vesicle does not contact the presynaptic membrane. (B, C) The arrival of an action potential opens the voltage-gated calcium channels; the influx of calcium ions permits the proper alignment of the synaptic vesicle with the presynaptic membrane by inducing slight rearrangements of both the docking complexes and the synaptic vesicle. (D) Once aligned properly, the synaptic vesicle fuses with the presynaptic membrane, opens, and releases its contents into the synaptic space. (E) To prevent an increase in the area of the presynaptic membrane, the excess membrane is recaptured as clathrin-coated pits and the membranes are recycled in the cytosol. (Modified from Kingsley, RE (1996) *Concise Text of Neuroscience*. Williams & Wilkins, Baltimore; p. 96.)

Figure 3.6 ● Some synaptic vesicles are formed in the soma and are transported into the axon terminal, whereas others are formed locally in the end-foot by budding from endosomes, and still others form via endocytosis of the presynaptic membrane. In order to prevent a constant release of neurotransmitters, the calcium level is reduced in the axon terminal by being actively exchanged for Na^+, by being sequestered in the smooth endoplasmic reticulum, as well as by being bound to cytoplasmic proteins. Furthermore, to maintain a constant size of the presynaptic membrane as it is enlarged by fusion of the synaptic vesicles with it, it is reduced by endocytosis via the formation of clathrin-coated vesicles that will then either join the endosomes or will form new synaptic vesicles.

Figure 3.7 ● Diagram depicting the difference between direct and indirect inhibition. Note that in direct inhibition, neuron D forms a synapse with the large multipolar neuron C, permitting transmission of information directly. In indirect inhibition, neuron A forms a synapse with the axon of neuron B and it is that other neuron that synapses with the large multipolar neuron C; thus the information is transmitted indirectly.

Figure 3.8 ● Neurons are classified into different categories depending on the number of processes they possess. Note that true unipolar neurons are rare in humans and that pseudounipolar neurons are also referred to as unipolar neurons.

Figure 3.9 ● Longitudinal section of a nerve fiber at the node of Ranvier. Note that as the two Schwann cell membranes approach each other they form cytoplasm-filled regions known as paranodal loops.

Figure 3.10 ● Myelination is very similar in the central nervous system where a single oligodendrocyte is capable of myelinating a single internode of numerous axons.

Figure 3.11 ● Myelin formation and structure in the peripheral nervous system. (A) The axon is surrounded by a Schwann cell. (B) The Schwann cell begins to rotate around the axon. (C) As rotation progresses, the mesaxon is being formed. (D) Continued rotation of the Schwann cell squeezes the cytoplasm out of the myelin sheath. (E) Higher magnification, displaying the inner and outer mesaxons as well as the major dense lines and intraperiod lines.

Figure 3.12 ● Propagation of the action potential depicted in three axons: (A, B) unmyelinated axons of different diameters, and (C) a myelinated axon. (A) Because the axon of smaller diameter offers greater axoplasmic resistance, a given localized current can hypopolarize the membrane to a shorter distance than an axon of larger diameter (indicated by the curved arrows) (B). Therefore, the propagation of action potentials occurs much faster in an axon of larger diameter than one of smaller diameter. (C) Myelinated axons offer less resistance than either of the two examples above, since the local current can only leave at the nodes of Ranvier. Therefore, the propagation of the action potential is saltatory, jumping from node to node, and the impulse travels much faster along a myelinated axon than along a nonmyelinated one.

Chapter 4

Figure 4.1 ● An example of an ionotropic effect occurring at a synapse indicating the events that occur before, during, and after the release of neurotransmitter substances.

Figure 4.2 ● A diagram of G-protein action during a metobotropic event. (A) Binding of epinephrine (E) to its beta-adrenergic receptor (β-AR) activates the replacement of GDP by GTP on the alpha-subunit of the G-protein. (B, C) The alpha-subunit dissociates from the G-protein and activates adenylate cyclase (AC) to convert ATP to cAMP, and epinephrine dissociates from its beta-adrenergic receptor. (D) GTPase cleaves an inorganic phosphate molecule from GTP, converting it into GDP and the alpha-subunit rejoins its G-protein.

Figure 4.3 ● Synthesis of catecolamines from tyrosine.

Figure 4.4 ● Synthesis of serotonin from tryptophan.

Figure 4.5 ● Synthesis of enkephalins from prepro-opiomelanocortin. ACTH, adrenocorticotropic hormone; MSH, melanocyte-stimulating hormone.

Figure 4.6 ● Acetylcholine synthesis and degradation.

Figure 4.7 ● (A) Synthesis of glycine from glucose. (B) Synthesis of gamma aminobutyric acid (GABA) from glutamate.

Figure 4.8 ● Glutamine–glutamate cycle.

Chapter 5

Figure 5.1 ● The spinal cord in a human. Note that the spinal processes of the vertebrae have been removed and that the dura mater and the arachnoid have been opened up so that the spinal cord may be viewed in its entire length. It should be evident that the spinal cord ends at L1,2, and the spinal nerves continue as the cauda equina within the lumbar cistern. It is the lumbar cistern that is accessed during a lumbar puncture to withdraw cerebrospinal fluid for laboratory examination.

Figure 5.2 ● The preferred method of performing a lumbar puncture is to have the patient assume the lateral decubitus position with the needle piercing the intervertebral space between L4 and L5.

Figure 5.3 ● Dorsal and ventral views of the spinal cord, depicting the gray matter as well as the fissures and funiculi of the white matter. Observe also that the dorsal and ventral roots join to form the spinal nerve.

Figure 5.4 ● The spinal cord and the relationship between the numbered spinal nerves and the bodies of the associated vertebrae.

Figure 5.5 ● A typical spinal nerve. The right side depicts the somatic nervous system, while the left side depicts the sympathetic nervous system. The preganglionic fibers are shown as solid lines and the postganglionic fibers are displayed as dashed lines. Note that the left side of the figure shows that the preganglionic sympathetic cell body is in the lateral horn of the thoracic and upper lumbar spinal cord levels (T1 to L1,2). The preganglionic fiber travels along the ventral rootlets, enters the spinal nerve, travels for a very short distance, and then leaves the spinal nerve via the white ramus communicans, which is the connection to the sympathetic chain ganglion. Once in the ganglion, there are three possibilities: (i) it may synapse with the postganglionic cell body located there; (ii) it may travel up or down the sympathetic trunk until it reaches another ganglion and synapse there with a postganglionic sympathethic cell body; or (iii) it may leave the sympathetic trunk altogether and travel to a collateral sympathetic ganglion and synapse there with a postganglionic sympathetic nerve cell body. The text describes the fate of the postganglionic fiber.

Figure 5.6 ● The sensory supply of the skin is established in bands, known as dermatomes, that represent the distribution of spinal nerves responsible for innervating that particular region. Note that there are overlaps between regions that are not indicated in these diagrams and also that there is no exact agreement among authorities concerning the precise distribution of the nerve supply (e.g., some authors state T4 as the spinal nerve responsible for the nipples, whereas others believe it to be spinal nerve T5).

Figure 5.7 ● Cross-section of the spinal cord showing its major landmarks. Observe that the various regions of the white matter are described on the left side and the regions of the gray matter on the right side of the diagram.

Figure 5.8 ● Cross-section of the spinal cord displaying the divisions of the gray matter into nine regions, referred to as Rexed laminae, as well as a tenth region, around the central canal of the spinal cord, known as the gray commissure (central gray, periependymal gray). These divisions are based on the cellular composition of the gray matter and they bear some relationship to the nuclei of the spinal cord (see Table 5.4).

Figure 5.9 ● The white matter of the spinal cord is organized into fiber bundles known as tracts or fasciculi. These tracts have relatively well-defined boundaries and are subdivided into three major groups: descending, ascending, and intersegmental. The descending fibers tracts convey motor information from higher centers, ascending tracts carry sensory information to higher centers, and intersegmental tracts (not illustrated here) transmit information between spinal cord segments and are therefore restricted to the spinal cord.

Figure 5.10 ● The vascular supply of the spinal cord. Note that there are two posterior spinal arteries but only a single anterior spinal artery. These three vessels, the coronal arteries, and branches of the anterior spinal artery vascularize the anterolateral aspect of the spinal cord, whereas the deep anterior aspect is vascularized by branches of the anterior sulcal artery. Much of the posterior aspect of the spinal cord is vascularized by branches of the posterior spinal arteries.

Figure 5.11 ● Ventral view of the spinal cord, drawn so that the bodies of all the vertebrae have been removed and the anterior spinal artery is displayed. Note that although there are 32 pairs of radicular arteries, only a few are displayed in this image and, to limit confusion, their anterior and posterior branches are not displayed. It should be noted that the anterior branches join the anterior spinal artery whereas their posterior branches join the posterior spinal arteries.

Chapter 6

Figure 6.1 ● Diagram of the brain from a lateral view.

Figure 6.2 ● (A) Diagram of the ventricles of the brain and central canal of the spinal cord *in situ*. (B) A three-dimensional representation of the ventricles of the brain.

Figure 6.3 ● Diagram of the medial view of a sagittal section of the brain.

Figure 6.4 ● Diagram of the base of the brain displaying the cranial nerves and the arterial supply. Note that the frontal lobes are pulled apart slightly to show the corpus callosum and the anterior cerebral arteries; also the right temporal lobe is sectioned to demonstrate the middle cerebral artery.

Figure 6.5 ● Diagram of the base of the brain displaying the location of the cranial nerves.

Figure 6.6 ● Diagram of a coronal section of the brain displaying the basal ganglia.

Figure 6.7 ● Superior and inferior views of the cerebellum.

Figure 6.8 ● Diagram of a lateral view of the cerebellum and medulla.

Figure 6.9 ● Diagram of the dorsal view of the brainstem.

Figure 6.10 ● Diagram of the ventral view of the brainstem.

Chapter 7

Figure 7.1 ● Three views of the dura mater. (A) The periosteal layer of the dura is reflected to demonstrate the branches of the middle meningeal artery and the tributaries of the middle meningeal vein. (B) The dura is opened to display the superior sagittal sinus and several lacunae lateralis. (C) The dura is reflected to display the arachnoid granulations in a lacuna lateralis.

Figure 7.2 ● Diagram of the dura and dural folds containing the venous sinuses.

Figure 7.3 ● Diagram of the dura and dural reflections housing the venous sinuses. Note that on the right-hand side the tentorium cerebelli was incised to display the trigeminal ganglion, the three divisions of the trigeminal nerve, and the contents of the cavernous sinus.

Figure 7.4 ● Diagram of a frontal section of the skull and brain to display the three meninges: the dura mater, arachnoid, and pia mater.

Figure 7.5 ● Diagram of the superior sagittal sinus housing arachnoid granulations.

Figure 7.6 ● Schematic diagram of an arachnoid granulation protruding into the superior sagittal sinus.

Figure 7.7 ● Schematic diagram of the spinal meninges.

Figure 7.8 ● Schematic diagram of the major dural sinuses. Note that the roof of the left orbit was removed to display the superior ophthalmic vein.

Figure 7.9 ● Diagram of the cavernous sinuses and their contents.

Figure 7.10 ● Hemisected skull demonstrating the flow of cerebrospinal fluid in the ventricles of the brain and in the subarachnoid spaces.

Chapter 8

Figure 8.1 ● Arterial supply of the spinal cord.

Figure 8.2 ● Venous drainage of the spinal cord.

Figure 8.3 ● Arterial supply of the brain. Note that the frontal lobes are spread apart somewhat to show the anterior cerebral arteries and that the right temporal lobe is severed to show the path and branches of the middle cerebral artery.

Figure 8.4 ● Region of the arterial cerebral circle displaying the blood supply to the choroidal plexus of the lateral ventricle.

Figure 8.5 ● Blood supply to the brain. Note that the right cerebral hemisphere has been sectioned in the frontal plane to expose the deeper branches of the middle cerebral artery.

Figure 8.6 ● (A) Arterial supply to the lateral aspect of the brain. Note that the temporal lobe is partially reflected to permit a view of the vessels lodged within the lateral fissure (of Sylvius). (B) Arterial supply of the medial aspect of the brain.

Figure 8.7 ● Arterial supply of the cerebellum.

Figure 8.8 ● Diagram of the ventral view of the cerebral arterial circle (of Willis).

Figure 8.9 ● Close-up diagram of the ventral view of the cerebral arterial circle.

Figure 8.10 ● Schematic diagrams of the distribution of the major branches of the arterial supply of the brainstem, showing five different cross-sections of the brainstem.

Figure 8.11 ● Lateral view of the venous drainage of the brainstem and cerebellum. Note that the cerebellum is sectioned.

Figure 8.12 ● Venous drainage of the brain. Note that the temporal lobe is sectioned and a window is cut into it to provide a view of the lateral ventricle.

Figure 8.13 ● Diagram of the deep venous drainage of the brain.

Chapter 9

Figure 9.1 ● Schematic diagram demonstrating the difference between the sympathetic nervous system (above) as it arises from spinal cord levels T1 to L1,2 and the spinal component of the parasympathetic nervous system (below) as it originates from the sacral spinal cord. ACh, acetylcholine.

Figure 9.2 ● Diagram of the sympathetic nervous system.

Figure 9.3 ● Diagram of the right and left sympathetic chain ganglia. Observe that the two sides fuse inferiorly to form the single ganglion impar.

Figure 9.4 ● Diagram of the sympathetic nervous system. Solid red lines represent preganglionic sympathetic fibers and dashed red lines represent postganglionic sympathetic fibers. GVE, general visceral efferent.

Figure 9.5 ● Diagram demonstrating the difference between the synapse occurring in a sympathetic chain ganglion and that occurring in a prevertebral ganglion. Solid red lines indicate preganglionic sympathetic fibers. Dashed red lines indicate postganglionic sympathetic fibers.

Figure 9.6 ● Diagram of the parasympathetic nervous system. Solid red lines represent preganglionic parasympathetic fibers and dashed red lines represent postganglionic parasympathetic fibers.

Figure 9.7 ● Schematic diagram of the parasympathetic innervation of the head. Solid red lines represent preganglionic parasympathetic fibers and dashed red lines represent postganglionic parasympathetic fibers.

Figure 9.8 ● Diagram of the spinal sensory and spinal motor pathways involved in urination. The black solid line indicates the sensation of imminent urination and the black dashed line indicates the inhibition of relaxation of the urinary bladder permitting postganglionic sympathetic fibers to cause contraction of the detrusor muscles, thus causing emptying of the bladder.

Chapter 10

Figure 10.1 ● Free nerve endings in the skin. The free nerve endings terminating in the epidermis lose their myelin sheath. Many free nerve endings have unmyelinated axons.

Figure 10.2 ● Peritrichial nerve endings. These free nerve endings spiral around the base of a hair follicle.

Figure 10.3 ● A section of dermis showing a Merckel's disc, Meissner's corpuscle, and Pacinian corpuscle.

Figure 10.4 ● Merkel's discs (corpuscles) terminate on the basal surface of the epidermis.

Figure 10.5 ● Meissner's corpuscles are located in dermal papillae of the skin.

Figure 10.6 ● Pacinian corpuscles are located in the dermis of the skin.

Figure 10.7 ● A corpuscle of Ruffini.

Figure 10.8 ● Right: an extrafusal skeletal muscle fiber. Left: a neuromuscular spindle containing the two types of intrafusal fibers—the nuclear bag fiber with multiple nuclei in the dilated central region and a nuclear chain fiber with a row of nuclei in its central region.

Figure 10.9 ● A Golgi tendon organ (neurotendinous spindle).

Figure 10.10 ● The direct pathway of the anterolateral system. Note the first order neuron in the dorsal root ganglion, the second order neuron in the dorsal horn of the spinal cord, and the third order neuron in the thalamus. The second order neuron sends collaterals to the reticular formation (RF). VPI, ventral posterior inferior; VPL, ventral posterior lateral.

Figure 10.11 ● The ascending sensory pathway that transmits nondiscriminative (crude) touch, pain, and temperature sensations from the body. (Modified from Gilman, S, Winans Newman, S (1992) *Essentials of Clinical Neuroanatomy and Neurophysiology*. FA Davis, Philadelphia; fig. 19.)

Figure 10.12 ● The spinothalamic (direct) and spinoreticular (indirect) pathways of the anterolateral system (ALS) transmitting nondiscriminative (crude) touch, pain, and temperature sensation from the body. VPI, ventral posterior inferior; VPL, ventral posterior lateral.

Figure 10.13 ● Somatosensory information to consciousness. VPI, ventral posterior inferior; VPL ventral posterior lateral.

Figure 10.14 ● Spinotectal, spinoreticular, and spinohypothalamic tracts of the indirect pathway of the anterolateral system. Note that the spinomesencephalic tract is not shown.

Figure 10.15 ● Primary and secondary somatosensory cortex and retroinsular cortex: three major cortical areas receiving somatosensory information from the thalamus. (A) Counter clockwise from top right: lateral view of the brain; a cross-section of the central sulcus (of Rolando); and the primary somatosensory cortex (postcentral gyrus, S-I) forming the posterior border of the sulcus. Note the components of the primary somatosensory cortex areas 3a, 3b, 1, and 2, and the cortical representation of the foot, trunk, hand, and face. The lateral view of the brain shows the exposed insular cortex, secondary somatosensory cortex (S-II), and retroinsular (RI) cortex. (B) Thalamocortical projections to the primary somatosensory cortex (S-I), secondary somatosensory cortex (S-II), and retroinsular cortex (RI). PO, posterior complex; VP, ventral posterior; VPI, ventral posterior inferior; VPS, ventral posterior superior. (Modified from Burt, AM (1993) *Textbook of Neuroanatomy*. WB Saunders, Philadelphia; figs 10.20, 10.22.)

Figure 10.16 ● Coronal section through the primary somatosensory cortex (postcentral gyrus), showing the sensory homunculus. Note that the amount of cerebral cortex representing each body part is proportional to the extent of its motor innervation.

Figure 10.17 ● The ascending sensory pathway relaying pain sensation from the viscera. VPL ventral posterior lateral.

Figure 10.18 ● The dorsal column–medial lemniscal pathway relaying discriminative (fine) touch and vibratory sense from the body to the somatosensory cortex. VPL, ventral posterior lateral.

Figure 10.19 ● (A) Two of the ascending sensory pathways to the cerebellum: the dorsal spinocerebellar tract transmitting sensory information from the lower limb and trunk, and the cuneocerebellar tract transmitting sensory information from the neck, upper limb, and upper trunk to the cerebellum. (B) Two of the ascending sensory pathways to the cerebellum: the ventral spinocerebellar tract transmitting sensory information from the lower trunk and lower limb, and the rostral spinocerebellar tract transmitting sensory information from the head and upper limb to the cerebellum.

Figure 10.20 ● Dermatomes of the skin. Each striped area represents the skin innervated by a single dorsal root ganglion (on each side).

Figure 10.21 ● Brown-Séquard syndrome. The figure shows the deficits resulting following hemisection of the right side of the spinal cord at the level of T12.

Figure 10.22 ● Location of a syphilitic lesion on the spinal cord.

Figure 10.23 ● Syringomyelia. (A) Damage of decussating fibers of the pain and temperature pathway. (B) Skin area in which there is loss of pain and temperature sensation following the development of syringomyelia.

Figure 10.24 ● Cross-section of the spinal cord and its arterial supply.

Figure 10.25 ● Gate control theory of pain. Stimulation of the C fibers transmitting nociception keeps the gate to higher brain centers open, whereas stimulation of the large-diameter A fiber closes the gate. (Modified from Heimart, L (1995) *The Human Brain*. Springer-Verlag, New York; fig. 9.2.)

Figure 10.26 ● Opiate-induced suppression of substance P (SP) release in the substantia gelatinosa of the spinal cord dorsal horn. Note the substance P release by the central process of the first order neuron where it synapses with a second order projection neuron of the spinothalamic tract. The local enkephalin-releasing inhibitory interneuron establishes a presynaptic contact on the axon terminal of the first order neuron inhibiting the release of substance P. ENK, enkephalin; VPL, ventral posterior lateral.

Figure 10.27 ● The descending analgesic pathways. (A) The midbrain periaqueductal gray matter contains enkephalinergic neurons whose axons descend to terminate in the nucleus raphe magnus (NRM) containing serotoninergic neurons. These neurons in turn descend bilaterally to terminate in the dorsal horn of the spinal cord. (B) Descending serotoninergic fibers arising from the NRM terminate on enkephalinergic and dynorphin-containing interneurons in the substantia gelatinosa of the spinal cord. The interneurons inhibit transmission of nociception via presynaptic inhibition of the first order afferent neurons. (C) Descending adrenergic fibers arising from the dorsolateral pontine reticular formation (DPRF) terminate bilaterally on inhibitory interneurons of the substantia gelatinosa of the spinal cord. The interneurons inhibit the second order projection neurons of the spinothalamic tract. (Modified from Burt, AM (1993) *Textbook of Neuroanatomy*. WB Saunders, Philadelphia; fig. 10.25.)

Chapter 11

Figure 11.1 ● The motor cortical areas: the primary motor cortex (M-I) and the secondary motor cortex (M-II) consisting of the premotor cortex (PMC), supplementary motor area (SMA), posterior parietal motor area (PMA), and frontal eye fields (FEF). Brodmann's areas are indicated in parentheses.

Figure 11.2 ● Coronal section through the primary motor cortex showing the motor homunculus. Note the somatotopic mapping. The cortical area devoted to each body part is proportional to the motor innervation received by the corresponding body part.

Figure 11.3 ● The fMRI images of the first four subjects (S1–S4) show the region of the primary motor cortex that was active during finger and toe movement, whereas the fMRI images of the second group (S5–S8) show the region of the primary cortex that was active during finger and elbow movement. (From Rao, SM *et al*. (1995) *Neurology* 45, 919–24. Courtesy of Lippincott, Williams & Wilkins, Baltimore.) (For color version, see website.)

Figure 11.4 ● The six layers of the neocortex and the different cell types located in each layer.

Figure 11.5 ● The origin, course, and termination of the corticospinal tracts. The lateral corticospinal tract synapses with lower motoneurons that innervate the upper and lower limb muscles, whereas the anterior corticospinal tract synapses with the lower motoneurons that innervate the muscles of the trunk. (Modified from Watson, C (1995) *Basic Human Neuroanatomy: an Introductory Atlas*. Little, Brown & Company, Boston; fig. 25.)

Figure 11.6 ● Horizontal section of the cerebrum showing the anterior limb, genu, and posterior limb of the internal capsule. Note the location of the corticospinal tract axons: A (upper extremity), T (trunk), and L (lower extremity) in the posterior half of the posterior limb of the internal capsule. Fibers carried by the corticonuclear (corticobulbar) tract pass through the genu, F (face).

Figure 11.7 ● The origin, course, and termination of the corticospinal tract.

Figure 11.8 ● The origin and termination of the corticospinal tract. FEF, frontal eye fields; PMA, posterior parietal motor area; PMC, premotor cortex; SMA, supplementary motor area.

Figure 11.9 ● Termination of the corticospinal tracts in the spinal cord. Note that the axons arising from the motor cortex terminate in the ventral horn of the spinal cord where they synapse with interneurons and lower motoneurons that innervate skeletal muscle. In contrast, the axons arising from the sensory cortex terminate in the dorsal horn of the spinal cord where they function in reflexes and modulate the transmission of sensory information to higher brain centers.

Figure 11.10 ● Somatotopic organization of the anterior horns of the spinal cord. (A) Cross-section of the cervical spinal cord showing the location of motoneurons innervating the upper limb and axial musculature. (B) Cross-section of the cervical spinal cord showing the upper limbs and trunk mapped on the ventral horns of the spinal cord.

Figure 11.11 ● The origin, course, and termination of the corticonuclear (corticobulbar) tract in the brainstem cranial nerve motor nuclei. (Modified from Watson, C (1995) *Basic Human Neuroanatomy*, 5th edn. Little, Brown & Company, Boston; fig. 22.)

Figure 11.12 ● The origin, course, and termination of the corticonuclear (corticobulbar) tract in the brainstem.

Figure 11.13 ● Corticonuclear (corticobulbar) tract projections to the facial motor nucleus. Note that the upper half of the facial motor nucleus receives bilateral corticonuclear projections, whereas the lower half of the facial motor nucleus receives only contralateral projections.

Figure 11.14 ● The origin, course, and termination of the tectospinal tract. The numbered midbrain structures are: 1, brachium of the superior colliculus; 2, pretectal area; 3, commissure of the superior colliculus; 4, spinotectal tract; 5, fibers from the lateral lemniscus. (Modified from Parent, A (1996) *Carpenter's Human Neuroanatomy*, 9th edn. Williams & Wilkins, Baltimore; fig. 11.18.)

Figure 11.15 ● The origin, course, and termination of the rubrospinal and reticulospinal tracts. (Modified from Haines, DE (2002) *Fundamental Neuroscience*. Churchill Livingstone, Philadelphia; fig. 24.9.)

Figure 11.16 ● The origin, course, and termination of the medial and lateral vestibulospinal tracts. MLF, medial longitudinal fasciculus. (Modified from Haines, DE (2002) *Fundamental Neuroscience*. Churchill Livingstone, Philadelphia; fig. 24.7.)

Figure 11.17 ● Somatotopic organization of the ventral horn of the spinal cord. (Modified from Fitzgerald, MJT (1996) *Neuroanatomy Basic and Clinical*, 3rd edn. WB Saunders, Philadelphia; fig. 13.1.)

Chapter 12

Figure 12.1 ● Connections between the cerebral cortex, thalamus, basal ganglia, cerebellum, brainstem, and spinal cord.

Figure 12.2 ● The caudate nucleus, putamen, and nucleus accumbens and their anatomical relation to the ventricular system.

Figure 12.3 ● Lateral view of the corpus striatum and its anatomical relation to the internal capsule.

Figure 12.4 ● Horizontal sections through the dorsal level (left) and the ventral level (right) of the corpus striatum.

Figure 12.5 ● Coronal section at the level of the thalamus, subthalamus, and hypothalamus.

Figure 12.6 ● Transverse section of the rostral midbrain, showing the substantia nigra.

Figure 12.7 ● Lateral view of the corpus striatum, amygdala, thalamus, and internal capsule.

Figure 12.8 ● Horizontal section of the brain at the level of the basal ganglia.

Figure 12.9 ● Afferent (input) projections to the caudate nucleus and putamen. (Modified from Watson, C (1995) *Basic Human Neuroanatomy*, 5th edn. Little, Brown & Company, Boston; fig. 39.)

Figure 12.10 ● Efferent (output) projections from the caudate nucleus and putamen. (Modified from Watson, C (1995) *Basic Human Neuroanatomy*, 5th edn. Little, Brown & Company, Boston; fig. 40.)

Figure 12.11 ● Afferent (input) projections to the globus pallidus. (Modified from Watson, C (1995) *Basic Human Neuroanatomy*, 5th edn. Little, Brown & Company, Boston; fig. 41.)

Figure 12.12 ● Efferent (output) projections from the globus pallidus. (Modified from Watson, C (1995) *Basic Human Neuroanatomy*, 5th edn. Little, Brown & Company, Boston; fig. 42.)

Figure 12.13 ● Principal output connections of the basal ganglia arising from the globus pallidus: the ansa lenticularis and lenticular fasciculus. These two fasciculi merge to form the thalamic fasciculus.

Figure 12.14 ● Sensory–motor loops. In the closed loop, information flows from the supplementary motor cortex to the caudate nucleus and putamen, and from there to the globus pallidus and the substantia nigra, continuing to the thalamus and then back to the supplementary motor cortex. In the open loop, input is contributed by the somatosensory cortex, primary motor cortex, and premotor cortex to the closed loop. (Modified from Noback, CR *et al*. (1996) *The Human Nervous System*, 5th edn. Williams & Wilkins, Baltimore; fig. 24.5.)

Figure 12.15 ● Oculomotor loops. In the closed loop, information flows from the frontal eye field to the caudate nucleus and then to the globus pallidus and the substantia nigra and from there to the thalamus and then back to the frontal eye field. In the open loop, input is contributed by the prefrontal cortex and the posterior parietal cortex to the closed loop. (Modified from Noback, CR *et al*. (1996) *The Human Nervous System*, 5th edn. Williams & Wilkins, Baltimore; fig. 24.7.)

Figure 12.16 ● Association loops. In the closed loop, information flows from the prefrontal cortex to the caudate nucleus and then to the globus pallidus and the substantia nigra and from there to the thalamus and then back to the prefrontal cortex. In the open loop, input is contributed by the premotor and posterior parietal cortex to the closed loop. (Modified from Noback, CR *et al*. (1996) *The Human Nervous System*, 5th edn. Williams & Wilkins, Baltimore; fig. 24.6.)

Figure 12.17 ● Limbic loops. In the closed loop information flows from the anterior cingulate gyrus and orbitofrontal cortex to the ventral striatum and the caudate nucleus and then to the ventral pallidum, globus pallidus, and substantia nigra, and from there to the thalamus and then back to the anterior cingulate gyrus and orbitofrontal cortex. In the open loop, input is contributed by the medial and lateral temporal lobe, hippocampus, amygdale, and entorhinal area to the closed loop. (Modified from Noback, CR *et al*. (1996) *The Human Nervous System*, 5th edn. Williams & Wilkins, Baltimore; fig. 24.8.)

Figure 12.18 ● Neural circuitry and neurotransmitters of the basal ganglia. (Modified from Young, PA & Young, PH (1997) *Basic Clinical Neuroanatomy*. Williams & Wilkins, Baltimore; fig. 8.10.)

Figure 12.19 ● Major pathways of the basal ganglia and their neurotransmitters. ACh, acetylcholine; DA, dopamine; ENK, enkephalin; GABA, gamma aminobutyric acid; GLU, glutamate and/or aspartate; SP, substance P. (Modified from Fix, JD (1995) Neuroanatomy, 2nd edn. Williams & Wilkins, Baltimore; fig. 21.4.)

Figure 12.20 ● The direct loop of the basal ganglia. GPe, globus pallidus (external segment); GPi, globus pallidus (internal segment); Snc, substantia nigra (pars compacta); Snr, substantia nigra (pars reticulata); STN, subthalamic nucleus. (Modified from Burt, AM (1993) *Textbook of Neuroanatomy*. WB Saunders, Philadelphia; fig. 16.3.)

Figure 12.21 ● The indirect loop of the basal ganglia. GPe, globus pallidus (external segment); GPi, globus pallidus (internal segment); Snc, substantia nigra (pars compacta); Snr, substantia nigra (pars reticulata); STN, subthalamic nucleus. (Modified from Burt, AM (1993) *Textbook of Neuroanatomy*. WB Saunders, Philadelphia; fig. 16.4.)

Figure 12.22 ● Subthalamic nucleus lesion. Note the neural circuitry modifications resulting in hyperkinetic disorders. (Modified from Young, PA & Young, PH (1997) *Basic Clinical Neuroanatomy*. Williams & Wilkins, Baltimore; fig. 8.11.)

Figure 12.23 ● Striatal lesion. Note the neural circuitry modifications resulting in hyperkinetic disorders. (Modified from Young, PA & Young, PH (1997) *Basic Clinical Neuroanatomy*. Williams & Wilkins, Baltimore; fig. 8.12.)

Figure 12.24 ● An individual with Huntington's chorea. Symptoms include choreic movements of the limbs and smacking of the lips and tongue. (Modified from Young, PA & Young, PH (1997) *Basic Clinical Neuroanatomy*. Williams & Wilkins, Baltimore; fig. 8.9.)

Figure 12.25 ● Decreased dopamine. Note the neural circuitry modifications resulting in hypokinetic disorders. (Modified from Young, PA & Young, PH (1997) *Basic Clinical Neuroanatomy*. Williams & Wilkins, Baltimore; fig. 8.13.)

Figure 12.26 ● Individual with Parkinson's disease. Symptoms include mask-like facial expression, flexed head and trunk, arms close to trunk, pill-rolling tremor of the hands, and slow, shuffling movements of the feet.

Chapter 13

Figure 13.1 ● The cerebellum: (A) midsagittal view, (B) dorsal view, and (C) ventral view.

Figure 13.2 ● The deep nuclei of the cerebellum.

Figure 13.3 ● Organization of the gray and white matter of the cerebellum.

Figure 13.4 ● Midsagittal section through the brainstem and vermis of the cerebellum.

Figure 13.5 ● The cerebellar cortex and its component cell layers.

Figure 13.6 ● (A) The zones and phylogenetic classification of the cerebellum. (B) The lobes and fissures of the cerebellum.

Figure 13.7 ● Sensory depiction in the cerebellar cortex. Note that visual and auditory information is relayed to the central region of the vermis. Somatosensory information is relayed to the vermal and paravermal zones of the anterior lobe, and the paravermal zone of the posterior lobe.

Figure 13.8 ● Posterior view of the brainstem and part of the left lobe of the cerebellum. Note the superior, middle, and inferior cerebellar peduncles.

Figure 13.9 ● Purkinje cell projections from the cerebellar cortex to the deep cerebellar nuclei and the vestibular nuclei.

Figure 13.10 ● Functional organization of the spinocerebellum, cerebrocerebellum, and vestibulocerebellum. (Modified from Martin, JH (1996) *Neuroanatomy, Text and Atlas*, 2nd edn. Appleton & Lange, Connecticut; fig. 10.6.)

Chapter 14

Figure 14.1 ● Neurons of the reticular formation. (A) A neuron whose primary axon divides into an ascending and a descending branch. (B) Note the intermingling of neuronal dendrites and axonal collateral branches.

Figure 14.2 ● The nuclei of the reticular formation in the brainstem.

Figure 14.3 ● The origin, course, and termination of the medial and lateral reticulospinal tracts.

Figure 14.4 ● The location of the horizontal and vertical gaze centers in the brainstem in (A) sagittal, and (B) transverse sections.

Figure 14.5 ● Descending pathways that modulate the transmission of nociception from the brainstem and spinal cord to higher brain centers. (Modified from Haines, DE (2002) *Fundamental Neuroscience*. Churchill Livingstone, Philadelphia; fig. 18.16.)

Chapter 15

Figure 15.1 ● Ventral view of the brainstem showing the cranial nerves.

Figure 15.2 ● The nuclei of the cranial nerves. The sensory nuclei are illustrated on the left, and the motor nuclei on the right.

Figure 15.3 ● A lesion involving the left oculomotor nerve results in the following symptoms ipsilateral to the side of the lesion: (i) lateral strabismus, (ii) ptosis (drooping of the upper eye lid), (iii) pupillary dilation, (iv) loss of accommodation of the lens, and (v) downward and outward deviation of the eye.

Figure 15.4 ● (A) Normal: When the head is tilted, the eyes rotate in the opposite direction. (B) Left superior oblique paralysis following a lesion to the trochlear nerve: the affected eye becomes extorted with consequent double vision. To minimize the double vision, the individual tilts her head toward the unaffected side which intorts the normal eye.

Figure 15.5 ● The trigeminal pathway for touch and pressure. Touch and pressure sensation from the orofacial structures is transmitted to the brainstem trigeminal nuclei, the main sensory nucleus, and the spinal nucleus via the central processes of first order pseudounipolar neurons whose cell bodies are located in the trigeminal ganglion. Second order neurons in these nuclei form the posterior and anterior trigeminal lemnisci which terminate in the ventral posterior medial nucleus of the thalamus (VPM). Third order neurons in the thalamus project to the postcentral gyrus. PCG, postcentral gyrus; S_c, subnucleus caudalis; S_i, subnucleus interpolaris; S_o, subnucleus oralis; V_1, ophthalmic division of the trigeminal nerve; V_2, maxillary division of the trigeminal nerve; V_3, mandibular division of the trigeminal nerve.

Figure 15.6 ● The trigeminal pathway for pain and temperature. Pain and temperature sensation from the orofacial structures is transmitted to the brainstem subnucleus caudalis (S_c) of the spinal trigeminal nucleus via the central processes of first order pseudounipolar neurons whose cell bodies are located in the trigeminal ganglion. Second order neurons from the subnucleus caudalis join the anterior trigeminal lemniscus to terminate in the ventral posterior medial nucleus of the thalamus (VPM). Third order neurons from the VPM terminate in the postcentral gyrus (PCG). For other abbreviations, see Fig. 15.5.

Figure 15.7 ● Branchiomotor innervation of the trigeminal nerve. The motor nucleus of the trigeminal nerve contains the motoneurons whose axons assemble to form the motor root of the trigeminal nerve. The motor root exits the pons and joins the mandibular division of the trigeminal nerve and distributes to the muscles of mastication, the mylohyoid, the anterior belly of the digastric, the tensor tympani, and the tensor veli palatini muscles to provide them with motor innervation. For abbreviations, see Fig. 15.5.

Figure 15.8 ● The jaw jerk reflex. The mesencephalic nucleus of the trigeminal nerve contains the nerve cell bodies of pseudounipolar neurons whose peripheral processes terminate in the muscle spindles of the masseter muscle. Sensory information (about muscle stretch) is carried by the central processes of these neurons to the ipsilateral main sensory and bilaterally to the motor nucleus of the trigeminal nerve. The motor neurons innervating the masseter muscle cause its contraction. For abbreviations, see Fig. 15.5.

Figure 15.9 ● The connections of the abducens nucleus with the oculomotor nucleus. Note that the abducens nucleus is the center for conjugate horizontal eye movement. It contains two populations of neurons: (i) lower motoneurons whose axons form the abducent nerve that innervates the lateral rectus muscle (LR); and (ii) interneurons whose axons cross the midline and join the contralateral medial longitudinal fasciculus (MLF) to synapse in the oculomotor nucleus with the motoneurons that innervate the medial rectus muscle (MR).

Figure 15.10 ● (A) Medial strabismus of the right eye due to paralysis of the lateral rectus muscle, resulting in diplopia (double vision). (B) To minimize the diplopia, the individual turns her head toward the side of the lesion, which abducts the normal eye.

Figure 15.11 ● A lesion of the left abducens nucleus will damage: (i) the lower motoneurons of the abducent nerve, paralyzing the left lateral rectus muscle (LR); and (ii) the interneurons that synapse with the lower motoneurons of the oculomotor nucleus that innervate the right medial rectus muscle (MR). The affected individual is unable to gaze to the side of the lesion (left) during conjugate horizontal eye movement. MLF, medial longitudinal fasciculus.

Figure 15.12 ● The origin and distribution of the facial nerve and its major branches.

Figure 15.13 ● Parasympathetic innervation of the facial nerve. GVE, general visceral efferent.

Figure 15.14 ● The gustatory pathway. Taste sensation is transmitted by cranial nerves VII (from the anterior two-thirds of the tongue), IX (from the posterior one-third of the tongue), and X (from the epiglottis). Taste sensation is relayed via the solitary tract to the solitary nucleus. The central tegmental tract arising from the solitary nucleus projects to the parabrachial nucleus and to the ventral posterior medial (VPM) nucleus of the thalamus, hypothalamus, and amygdala. The VPM nucleus of the thalamus projects to the gustatory cortex residing in the parietal operculum and the parainsular cortex. (Modified from Fix, JD (1995) *Neuroanatomy*. Williams & Wilkins, Media; fig. 20.2.)

Figure 15.15 ● The origin and distribution of the glossopharyngeal nerve and its major branches.

Figure 15.16 ● Innervation by the glossopharyngeal nerve: (A) special visceral afferent (SVA; taste); (B) general visceral afferent (GVA); (C) special visceral efferent (SVE; skeletal motor); and (D) general visceral efferent (GVE; parasympathetic).

Figure 15.17 ● The origin and distribution of the vagus nerve and its major branches. GSA, general somatic afferent; GVA, general visceral afferent; SVA, special visceral afferent.

Figure 15.18 ● Innervation by the vagus nerve: (A) general somatic afferent (GSA), general visceral afferent (GVA), and special visceral afferent (SVA; taste); (B) special visceral efferent (SVE; skeletal motor); and (C) general visceral efferent (GVE; parasympathetic).

Figure 15.19 ● The origin and distribution of the spinal accessory nerve and its major branches.

Figure 15.20 ● The origin and distribution of the hypoglossal nerve.

Chapter 16

Figure 16.1 ● Anatomy of the eye. The eye consists of three layers. The outer layer includes the cornea anteriorly, which becomes continuous with the sclera that covers the remainder of the eye. The middle layer consists of the vascular choroid, containing blood vessels and is continuous with the ciliary body and iris anteriorly. The inner layer is formed by the retina consisting of the non-neural pigment epithelium and the multilayered neural retina. Ganglion cell axons from the retina converge at the posterior aspect of the eye to form the optic nerve.

Figure 16.2 ● Layers of the retina and component cells. Note that light has to pass from the front of the eye through the vitreous body and all of the retinal layers to finally reach the receptor cells, rods, and cones.

Figure 16.3 ● Schematic representation of the retinal receptor cells outer segment: (A) the outer segment of a rod; and (B) the outer segment of a cone.

Figure 16.4 ● Schematic diagram of the eyes, optic nerves, optic chiasma, and optic tracts. Each optic nerve contains visual information from the ipsilateral eye. Fibers from the temporal half of each retina course along the lateral aspect of the optic chiasma to join the ipsilateral optic tract. In contrast, fibers from the nasal half of each retina course in the central region of the optic chiasma where they cross to join the contralateral optic tract. Thus each optic tract carries information from both eyes.

Figure 16.5 ● The visual pathways. Ganglion cell axons (axons of second order neurons) leaving the retina form the optic nerve. The ganglion cell axons arising from the temporal half of each retina pass along the lateral aspect of the optic chiasma to join the ipsilateral optic tract. The ganglion cell axons arising from the nasal half of each retina cross at the optic chiasma to join the contralateral optic tract. Ganglion cell axons terminate in the lateral geniculate nucleus of the thalamus and the superior colliculus and pretectal area of the midbrain. Third order neurons of the lateral geniculate nucleus project via the geniculocalcarine tract (optic radiation, thalamocortical projections) to the primary visual cortex (Brodmann's area 17) located in the banks of the calcarine sulcus on the medial surface of the occipital lobe.

Figure 16.6 ● The visual pathway.

Figure 16.7 ● Retinal ganglion cell projections to the lateral geniculate nucleus of the thalamus. Note that layers 1, 4, and 6 of the lateral geniculate nucleus receive visual information from the contralateral retina, whereas layers 2, 3, and 5 receive visual information from the ipsilateral retina. (Modified from Nolte, J (1999) *The Human Brain, An Introduction to Its Functional Anatomy*, 5th edn. Mosby, St Louis, Missouri; fig. 17.25C.)

Figure 16.8 ● Visual field representation in the retina and primary visual cortex.

Figure 16.9 ● (A) Visual field representation in the visual pathway: T, temporal half of the visual field; N, nasal half of the visual field; SC, superior colliculus; LGN, lateral geniculate nucleus. In the right retina and right optic nerve, the image from the visual field is backwards and upside down. Note that the left eye has a shield over it, thus no visual information is perceived by that eye. At the level of the optic chiasma, the ganglion cell axons coursing in the medial half of the right optic nerve decussate to the opposite side to course in the medial half of the left optic tract, to terminate in the left lateral geniculate nucleus. In contrast, the ganglion cell axons coursing in the lateral half of the right optic nerve remain ipsilaterally and course in the lateral half of the right optic tract, to terminate in the right lateral geniculate nucleus. Visual information is relayed to the primary visual cortex in a banded pattern. The alternating clear bands represent the areas occupied by the axons of the optic radiations relaying visual information from the left eye. (B) Visual field representation in the primary visual cortex. The peripheral area of the visual field is represented in the anterior region of the primary visual cortex on the medial surface of the occipital lobe. In contrast, the central or macular area of the visual field is represented in the posteriormost region of the primary visual cortex. (Modified from Fitzgerald, MJT, Folan-Curran, J (2002) *Clinical Neuroanatomy and Related Neuroscience*. WB Saunders, New York; fig. 25.10.)

Figure 16.10 ● The pupillary light reflex pathway.

Figure 16.11 ● The pupillary light reflex pathway. When light is flashed into one eye, normally, both pupils constrict simultaneously as follows. The information is transmitted from the illuminated eye via the optic nerve and then the optic tract to the pretectal area in the midbrain. The pretectal area projects to the Edinger–Westphal nucleus bilaterally—connecting it to the parasympathetic neurons of both sides, thus initiating a bilateral pupillary response. The Edinger–Westphal nucleus contains the cell bodies of preganglionic parasympathetic neurons whose axons join the oculomotor nerve of its respective side, to terminate in the ciliary ganglion. In the ciliary ganglion, the preganglionic parasympathetic terminals synapse with the postganglionic parasympathetic neurons whose axons project via the short ciliary nerve of the trigeminal nerve to the sphincter pupillae muscle, causing the pupil to constrict.

Figure 16.12 ● The pupillary dilation pathway. Axons arising from the hypothalamus form the hypothalamospinal tract, which descends ipsilaterally to terminate in the ciliospinal center of the intermediolateral cell column of the spinal cord at the T1 level. Preganglionic sympathetic neurons project their axons arising from the ciliospinal center to the superior cervical ganglion where they synapse with postganglionic sympathetic neurons. The postganglionic neurons give rise to axons that form a perivascular plexus, following vessels to the orbit where they terminate in the dilator pupillae muscle, causing pupillary dilation. (Modified from Fix, JD (1995) *Neuroanatomy*. Williams & Wilkins, Media; fig. 17.4.)

Figure 16.13 ● The pupillary dilation pathway.

Figure 16.14 ● The convergence accommodation (near) reflex pathway. Visual input passes via the visual pathway to the visual association cortex. It is believed that the visual association cortex projects bilaterally, to the superior colliculus and/or the pretectal area, both of which in turn project to Perlia's nucleus of the oculomotor nuclear complex. Perlia's nucleus of each side projects to the Edinger–Westphal nucleus and the medial rectus subnucleus of the oculomotor nucleus. Each oculomotor nucleus stimulates the contraction of the ipsilateral medial rectus muscle, causing adduction of the eye. The Edinger–Westphal nucleus projects preganglionic parasympathetic fibers to the ciliary ganglion where they synapse with postganglionic parasympathetic neurons that innervate the sphincter pupillae (pupillary constriction) and the ciliary muscle (lens accommodation) causing the lens to thicken for near vision. Note that the accommodation reflex is as described above, and is a bilateral response.

Figure 16.15 ● The convergence accommodation (near) reflex pathway.

Figure 16.16 ● The corneal blink reflex. When a wisp of cotton is gently brushed against the cornea of one eye, both eyes blink. Touch sensation is transmitted from the cornea via the pseudounipolar neurons of the trigeminal ganglion to the ipsilateral spinal nucleus and main sensory nucleus of the trigeminal nerve. The spinal and main sensory nuclei of the trigeminal nerve both send bilateral projections to the facial motor nuclei where they synapse with the motoneurons that innervate the orbicularis oculi muscles, causing simultaneous blinking of both eyes. GSA, general somatic afferent; SVE, special visceral efferent.

Figure 16.17 ● The corneal blink reflex.

Figure 16.18 ● (A) The visual fields and their representation on the retina. (B) Visual field loss and the consequent deficits.

Figure 16.19 ● Lesions at various points along the visual pathway and consequent visual field deficits: A, lesion of the optic nerve: total blindness in the ipsilateral eye; B1, unilateral lesion of the temporal (noncrossing) fibers of the optic chiasma: ipsilateral nasal hemianopsia; B2, bilateral lesion of the temporal (noncrossing) fibers of the optic chiasma: binasal heteronymous hemianopsia; C, lesion of the crossing fibers of the optic chiasma: bitemporal heteronymous hemianopsia; D, lesion of the optic tract: contralateral homonymous hemianopsia; E, lesion of Meyer's loop (lower division of the optic radiations): contralateral upper homonymous quadrantanopsia; F, lesion of the upper division of the optic radiations: contralateral lower homonymous quadrantanopsia; G, lesion of the upper and lower divisions of the optic radiations or the primary visual cortex: contralateral homonymous hemianopsia with macular sparing.

Chapter 17

Figure 17.1 ● The external, middle, and inner ear. (Modified from Canfield Willis, MC (1996) *Medical Terminology*. Williams & Wilkins, Baltimore; plate 26.)

Figure 17.2 ● The transmission of sound waves from the outer to the inner ear. Sound waves strike the tympanic membrane, causing it to vibrate. The vibrations of the tympanic membrane are transmitted to the three bones in the middle ear which in turn transmit the vibrations to the oval window. Oscillations of the oval window are then sequentially transmitted to the perilymph of the scala vestibuli and the endolymph of the cochlear duct, and then to the basilar membrane. Sound is detected by the receptor hair cells of the organ of Corti resting on the basilar membrane. Vibrations are conveyed to the perilymph in the scala tympani which cause the elastic membrane covering the round window to release pressure waves into the middle ear cavity.

Figure 17.3 ● Components of the inner ear. (A) The vestibulocochlear apparatus. (B) Cross-section through the three scalae of the cochlea: the scala vestibuli, scala media (cochlear duct), and scala tympani. (C) The organ of Corti resting on the basilar membrane. (D) A sensory hair cell.

Figure 17.4 ● The main efferent projections from the cochlear nuclei. (Modified from Burt, AM (1993) *Textbook of Neuroanatomy*. WB Saunders, Philadelphia; fig. 12.15.)

Figure 17.5 ● The pathway of auditory stimulation from the external auditory meatus to the cochlear nuclei in the brainstem.

Figure 17.6 ● The principal ascending auditory pathways emerging from the anteroventral cochlear nucleus. (Modified from Burt, AM (1993) *Textbook of Neuroanatomy*. WB Saunders, Philadelphia; fig. 12.16.)

Figure 17.7 ● The principal ascending auditory pathways emerging from the posteroventral and dorsal cochlear nuclei. (Modified from Burt, AM (1993) *Textbook of Neuroanatomy*. WB Saunders, Philadelphia; fig. 12.17.)

Figure 17.8 ● Lateral view of the cerebral hemisphere showing the location of the primary auditory cortex and an illustration of its organization. (Modified from Matthews, G (2001) *Neurobiology*. Blackwell Publishing, Oxford; fig. 17.14.)

Figure 17.9 ● The olivocochlear pathway arises from the superior olivary nuclei and terminates in the organ of Corti where it inhibits the transmission of auditory information to higher brain centers. (Modified from Burt, AM (1993) *Textbook of Neuroanatomy*. WB Saunders, Philadelphia; fig. 12.18.)

Figure 17.10 ● The sound attenuation reflex. Auditory information is transmitted from the organ of Corti via the central processes of bipolar sensory neurons to the ipsilateral ventral cochlear nucleus. Subsequent connections are bilateral. Information is then transmitted sequentially to the superior olivary nucleus which in turn projects to the trigeminal motor and facial motor nuclei. The trigeminal motor nucleus projects to the tensor tympani and the facial motor nucleus projects to the stapedius muscle, causing their contraction and dampening of auditory input.

Chapter 18

Figure 18.1 ● The external, middle, and inner ear. (Modified from Canfield Willis, MC (1996) *Medical Terminology*. Williams & Wilkins, Baltimore; plate 26.)

Figure 18.2 ● Schematic illustration showing the vestibulocochlear apparatus of the inner ear embedded in the petrous portion of the temporal bone.

Figure 18.3 ● The macula. (A) Location of the macula within the utricle and saccule. (B) The utricular macula. (C) Higher magnification of the utricular macula illustrating the otoliths on the otolithic membrane, the receptor cells, and the peripheral fiber terminals of the vestibular nerve synapsing with the receptor hair cells. (D) Higher magnification of a receptor hair cell showing its single kinocilium and numerous microvilli.

Figure 18.4 ● Three-dimensional view of the semicircular canals. (A) Location of the crista ampullaris within the ampullae of the three semicircular canals. (B) An enlarged crista ampullaris. (C) Higher magnification of a sectioned crista ampullaris showing the cupula, receptor hair cells, and peripheral processes of the vestibular nerve synapsing with the receptor hair cells (D).

Figure 18.5 ● Function of the semicircular canals in balance maintenance. (A, B) The maculae detect spatial orientation of the head relative to gravity and linear acceleration or deceleration forces. (C–E) The cristae respond to endolymphatic flow. They detect angular acceleration or deceleration (rotational movement) of the head (as in turning or tilting the head). As a person at rest (C) begins to rotate (D), the crista ampullaris is tilted by the flow of the endolymph opposite to the direction of the rotation. When the person stops rotating (E), the crista ampullaris is tilted by the flow of the endolymph in the same direction as the rotation.

Figure 18.6 ● (A) The vestibulocochlear apparatus, termination of the central processes of the vestibular nerve in the vestibular nuclei, and their projections to the oculomotor, trochlear, and abducens nuclei. VPI, ventral posterior inferior; VPL, ventral posterior lateral. (B) The termination of the central processes of the first order afferent neurons of the vestibular ganglion in the brainstem vestibular nuclei and the cerebellum.

Figure 18.7 ● The vestibular nuclei and their ascending and descending projections.

Figure 18.8 ● The main central projections of the vestibular system. Output fibers from the vestibular nuclei join the ascending medial longitudinal fasciculus (MLF) to terminate in the motor nuclei innervating the extraocular muscles where they function in vestibulo-ocular reflexes. Output fibers from the vestibular nuclei joining the descending MLF and the lateral vestibulospinal tracts, terminate in the motor horn of the spinal cord where they function in postural reflexes.

Figure 18.9 ● Central connections mediating compensatory horizontal eye movement in response to horizontal head movement. LR, lateral rectus muscle; MLF, medial longitudinal fasciculus; MR, medial rectus muscle.

Figure 18.10 ● Central connections mediating compensatory vertical (upward) eye movement in response to downward (forward) movement of the head. IO, inferior oblique muscle; IR, inferior rectus muscle; SO, superior oblique muscle; SR, superior rectus muscle.

Figure 18.11 ● Central connections mediating compensatory vertical (downward) eye movement in response to upward (backward) movement of the head. IO, inferior oblique muscle; IR, inferior rectus muscle; MLF, medial longitudinal fasciculus; SO, superior oblique muscle; SR, superior rectus muscle.

Figure 18.12 ● Vestibular nystagmus: (A) slow phase, and (B) rapid phase. (Modified from Netter, FH (1983) *The Ciba Collection of Medical Illustrations*, Vol. 1 *The Nervous System*, Part I *Anatomy and Physiology*. CIBA, New Jersey; plate 31.)

Chapter 19

Figure 19.1 ● (A) The olfactory bulb and tract. The olfactory receptor cell axons pass through the cribriform plate of the ethmoid bone to enter the cranial vault where they terminate and synapse in the olfactory bulb. (B) The olfactory epithelium (neuroepithelium). Note the olfactory receptor cells—the first order neurons of the olfactory pathway. (C) Enlargement of an olfactory knob.

Figure 19.2 ● Olfactory transduction. Odorous substances dissolve in the mucus layer overlying the olfactory neuroepithelium and then bind to odorant-binding proteins that move them through the mucus. The odorous substances subsequently bind to the receptors in the olfactory epithelium, which in turn activates a second messenger pathway.

Figure 19.3 ● The layers and neuronal circuitry of the olfactory bulb. The glomeruli are synaptic complexes where the central processes of the olfactory receptor cells synapse with the neurons in the olfactory bulb.

Figure 19.4 ● The olfactory bulb, anterior olfactory nucleus, and olfactory tract, and its division into the medial and lateral olfactory striae.

Figure 19.5 ● The connections of the olfactory system. The olfactory receptor cell axons pass through the cribriform plate of the ethmoid bone to terminate in the olfactory bulb. Each olfactory bulb is continuous posteriorly with the olfactory tract, which divides into the medial, intermediate, and lateral olfactory striae. From there, olfactory information is transmitted to the amygdala, the primary olfactory cortex, the olfactory tubercle, the anterior perforated substance, the septal nuclei, and the contralateral olfactory bulb via the anterior commissure. (Modified from Fix, JD (1995) *Neuroanatomy*, 2nd edn. Williams & Wilkins, Baltimore; fig. 20.1; and Burt, AM (1993) *Textbook of Neuroanatomy*. WB Saunders, Philadelphia; fig. 13.13.)

Chapter 20

Figure 20.1 ● The cortical structures of the limbic lobe: the subcallosal, cingulate, and parahippocampal gyri and the hippocampal formation.

Figure 20.2 ● (A) Dissection of the right cerebral hemisphere illustrating the interior of the lateral ventricle with the hippocampus, dentate gyrus, and fornix. (B) Coronal section exposing the fiber pathways. (C) Coronal section exposing the three sectors of the hippocampus proper.

Figure 20.3 ● (A) Coronal section through the hippocampus and its associated structures. (Modified from Snell, RS (1997) *Clinical Neuroanatomy for Medical Students*, 4th edn. Lippincott–Raven, New York; fig. 16.4.) (B) Sagittal sections of the hippocampal formation illustrating the association of the hippocampus and dentate gyrus to the inferior horn of the lateral ventricle, the caudate nucleus, and the amygdala. The respective layers of the hippocampus and the dentate gyrus are illustrated in the top view.

Figure 20.4 ● Dissection of the superior surface of the cerebrum to reveal the superior surface of the corpus callosum. (Modified from Snell, RS (1997) *Clinical Neuroanatomy for Medical Students*, 4th edn. Lippincott–Raven, New York; fig. 16.4.)

Figure 20.5 ● Dissection of the medial surface of the cerebral hemisphere showing the main components of the limbic system.

Figure 20.6 ● A transverse section through the temporal lobe at the level of the hippocampus and dentate gyrus. The main pathways connecting the hippocampus, dentate gyrus, and entorhinal cortex are shown.

Figure 20.7 ● The intrinsic circuitry of the hippocampal formation.

Figure 20.8 ● The relationship of the amygdala and hippocampal formation. The fornix, the principal efferent pathway of the hippocampal formation, and its termination, the mammillary body, are also shown.

Figure 20.9 ● Three-dimensional view of the relationships between the hippocampus, the fornix, and the mammillary bodies.

Chapter 21

Figure 21.1 ● Sagittal section through the brainstem and part of the cerebral hemispheres illustrating the hypothalamus and its neighboring structures, the diencephalon and midbrain.

Figure 21.2 ● Schematic ventral view of the brain illustrating the hypothalamus and surrounding structures.

Figure 21.3 ● Schematic sagittal section of the brainstem illustrating the hypothalamic nuclei. (A) Nuclei of the medial zone of the hypothalamus positioned medial to the fornix and mammillothalamic tract. (B) Nuclei of the lateral zone of the hypothalamus positioned lateral to the fornix and the mammillothalamic tract.

Figure 21.4 ● Coronal sections through the hypothalamus at the level of: (A) the preoptic region, and (B) the supraoptic region.

Figure 21.5 ● Coronal sections through the hypothalamus at the level of: (A) the supraoptic region, and (B) the tuberal region.

Figure 21.6 ● Coronal sections through the hypothalamus at the level of: (A) the anterior mammillary region, and (B) the posterior mammillary region.

Figure 21.7 ● Schematic diagram of the hypothalamus illustrating its component nuclei. (Modified from Netter, NH (1983) *The CIBA Collection of Medical Illustrations*. Vol. 1, part 1. CIBA, New Jersey; p. 207, plate 55.)

Figure 21.8 ● Hypothalamic control of the pituitary gland (neural path). ADH, antidiuretic hormone.

Figure 21.9 ● Hypothalamic control of the pituitary gland (non-neural path).

Figure 21.10 ● The paraventricular and supraoptic nuclei of the hypothalamus. (Modified from Netter, NH (1983) *The CIBA Collection of Medical Illustrations*. Vol. 1, part 1. CIBA, New Jersey; p. 211, plate 59.)

Figure 21.11 ● The interaction between the hypothalamus and anterior pituitary gland. LRH, lutein-releasing hormone; SRH, somatotropin-releasing hormone; for other abbreviations see Fig. 21.9. (Modified from Netter, FH (1983) *The CIBA Collection of Medical Illustrations*. Vol. 1, part 1. CIBA, New Jersey; p. 210, plate 58.)

Figure 21.12 ● Vascularization of the hypothalamus and the pituitary gland. (Modified from Netter, FH (1983) *The CIBA Collection of Medical Illustrations*. Vol. 1, part 1. CIBA, New Jersey; p. 209, plate 57.)

Figure 21.12 ● (*continued*)

Chapter 22

Figure 22.1 ● A midsagittal section through the brainstem and part of the overlying cerebral hemisphere. Note the thalamus and its neighboring diencephalic structures and midbrain.

Figure 22.2 ● A horizontal section through the cerebral hemispheres showing the dorsal thalamus, basal ganglia, and internal capsule.

Figure 22.3 ● Schematic representation of the dorsal surface of the thalamus on a horizontally sectioned brain. Part of the cerebral hemisphere has been removed to expose deeper structures such as the thalamus, third ventricle, caudate nucleus, and hippocampus.

Figure 22.4 ● (A) Schematic representation of the thalamus showing its dorsal and lateral surfaces. (B) Cross-section through the thalamus showing the midline, medial, intralaminar, and lateral groups of nuclei.

Figure 22.5 ● Schematic representation of the dorsal surface of the thalamus. (A) Thalamic nuclei and connections of the component nuclei of the thalamus. LGB, lateral geniculate body; MGB, medial geniculate body. (B) Lateral surface of the right cerebral hemisphere. (C) Medial surface of the right cerebral hemisphere illustrating the cortical areas where the thalamic nuclei project. (Modified from Fitzgerald, MJT, Folan-Curran, J (2002) *Clinical Neuroanatomy and Related Neuroscience*. WB Saunders, New York; fig. 22.1.)

Chapter 23

Figure 23.1 ● Lateral view of the cerebral hemisphere showing the principal gyri and sulci of the cerebral cortex.

Figure 23.2 ● The different types of neurons of the cerebral cortex.

Figure 23.3 ● The histology of the cerebral cortex, illustrating the layers and cell types in each of the layers.

Figure 23.4 ● (A) Schematic representation of the major association fiber system (lateral view). (B) Three-dimensional schematic representation of the major association fiber systems (lateral view).

Figure 23.5 ● (A) Horizontal schematic representation of the brain showing the fiber connections of the genu and splenium of the corpus callosum. (B) Coronal schematic representation of the brain showing the fibers of the anterior commissure and the body of the corpus callosum. (Modified from Young, PA & Young, PH (1997) *Basic Clinical Neuroanatomy*. Williams & Wilkins, Baltimore; fig. 15.4.)

Figure 23.6 ● Lateral view of the brain showing four of the five lobes of the cerebrum.

Figure 23.7 ● Views of the cerebral hemisphere showing the cytoarchitectural map of the cerebral cortex: (A) lateral view, and (B) medial view. Numbers represent Brodmann's areas. (Modified from Noback, CR et al. (1996) *The Human Nervous System*. Williams & Wilkins, Media; figs 25.5, 25.6)

Figure 23.8 ● Lateral view of the cerebral hemisphere showing the functional areas of the cerebral cortex. (Modified from Young, PA, Young, PH (1997) *Basic Clinical Neuroanatomy*. Williams & Wilkins, Baltimore; fig. 15.6c.)

Figure 23.9 ● Coronal section through the cerebral hemisphere showing homunculi of the primary somatosensory cortex (left) and the primary motor cortex (right).

Figure 23.10 ● The location and functional organization of the primary auditory cortex. (Modified from Matthews, G (2001) *Neurobiology*. Blackwell Publishing, Oxford; fig. 17.14.)

Figure 23.11 ● Diagram showing the possible progression of neural transmission from the visual cortex through the cortical areas associated with speech to the primary motor cortex in the production of speech. For example, when an individual sees an object and is asked to name it, information is relayed from (1) the visual cortex (Brodmann's areas 17, 18, and 19) to (2) the angular gyrus (Brodmann's area 39), to (3) Wernicke's area (Brodmann's area 22), by way of (4) the arcuate fasciculus, to (5) Broca's area of speech (Brodmann's areas 43, 44, and 45), and finally to (6) the primary motor cortex (Brodmann's area 4) which gives rise to the corticonuclear tract that terminates in the brainstem motor nuclei of the cranial nerves associated with vocalization. (Modified from Noback, CR et al. (1996) *The Human Nervous System*. Williams & Wilkins, Media; fig. 25.7.)

Figure 23.12 ● Neural pathways associated with: (A) hearing a word that is then spoken, and (B) reading a word that is then spoken.

Figure 23.13 ● Functions associated with the dominant and nondominant cerebral hemispheres. (Modified from Noback, CR *et al*. (1996) *The Human Nervous System*, 5th edn. Williams & Wilkins, Baltimore; fig. 25.9.)