



Hans J. ten Donkelaar

# Clinical Neuroanatomy

Brain Circuitry and Its Disorders

 Springer

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Brain Circuitry and Its Disorders

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*Cover illustration:* Lateral view of the left hemisphere of the human brain  
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## Preface

During the last decade, there have been tremendous technical developments to study the human central nervous system (CNS) and its connectivity. Modern imaging techniques such as positron emission tomography (PET) and functional MRI (fMRI) have greatly improved our knowledge of the circuitry of the human CNS. New developments in MR imaging such as diffusion tensor imaging (DTI) allow the visualization of at least the major fibre connections in the human CNS. Much of our knowledge of the organization of the CNS, however, we still owe to the classic studies of Vicq d'Azyr, Edinger, Dejerine, Flechsig, Brodmann, the Vogts, Foerster and many others, anatomists as well as neurologists, who painstakingly examined fresh and later fixed brains and laid down the framework for the main circuits in the human brain and spinal cord.

Knowledge of how the various parts of the CNS are interconnected to form functional systems is a prerequisite for the proper understanding of data from other fields in the neurosciences. Connections define the functions of neurons. Information flows along connections, growth factors and also viruses are transported along connections, epileptic discharges are spread through connections, and when they are deprived of connections, neurons pine away and may die through retrograde degeneration (dying back degeneration) or through anterograde transneuronal degeneration. Neuronal death in amyotrophic lateral sclerosis, spinocerebellar disorders and various intoxications, the distribution of neurofibrillary tangles in Alzheimer disease and atrophy in olivopontocerebellar degeneration progress through neuronal connections. Parkinson disease may begin in the caudal brain stem, years before affecting the substantia nigra, and then it progresses rostrally to reach limbic and cortical areas. The basal nucleus of Meynert and the extended amygdala are involved in some of the most devastating neuropsychiatric disorders such as schizophrenia and Alzheimer disease.

This book is on brain circuitry (“systems anatomy”) and its disorders. It tries to bridge the gap between neuroanatomy and clinical neurology and emphasizes human and primate data in the context of the many disorders of brain circuitry so common in neurological practice. The idea for this book arose when I moved from the Department of Anatomy and Embryology to the Department of Neurology, both of the Radboud University Nijmegen Medical Centre. This resulted in a fruitful collaboration with neurologists and especially the neuropathologists Pieter Wesseling and Martin Lammens. George Padberg and Berry Kremer made this project possible. I am grateful to Anthony Lohman, Rudolf Nieuwenhuys, Jan Voogd and Antoine Keyser for their support during my academic career from comparative and developmental neuroanatomy to clinical neuroanatomy. This book contains some of the fine, but sparse, anterograde degeneration studies on fibre connections in the human brain by Hans Kuypers, Jaap Schoen, William Mehler and Peter Nathan.

Throughout the book, “Clinical cases” are included to illustrate where normal brain circuitry may be interrupted and to what effect. These cases were kindly provided by clinical colleagues, neurologists, neuroradiologists and neuropathologists or, when exceptional, taken from the literature. Contributions were provided by the co-authors of the various chapters, Peter van Domburg and Akira Hori in particular, and by, among others, Anna Cantagallo (Ferrara), Anna Lavezzi (Milan), Luigi Mossuto-Agatiello (Rome), Emmanuel Pierrat-Deseilligny (Paris), Maria Thom and John Rothwell (London), Ferdinand Binkofski (Lübeck),

Bernhard Bogerts (Magdeburg), Heiko Braak and Kelly Del Tredici-Braak (Ulm), Adrian Danek (Munich), Peter Urban (Hamburg), Arnulf Koeppen (Albany), Tom Scammell (Boston), Ralph Adolphs (Iowa City), Suzanne Corkin (Cambridge, MA), Nancy Rempel-Clower (Grinnell), Maya Mimuro and Mari Yoshida (Aichi), Hiroyasu Akatsu (Toyohashi), Ryuji Sakakibara (Toho), Hiroaki Yaguchi and Ichiro Yabe (Sapporo), Erwin van Ingelghem and Michel van Zandijcke (Brugge), Gea Drost, Myrthe Hol, Hennie Schoonderwaldt, Nens van Alfen, Frank Erik de Leeuw, Jurgen Schelhaas, Henk ter Laak, Henri Timmers and Gert van Dijk (Nijmegen), Jan Geelen (Nijmegen/Enschede), Gerard van Noort (Enschede), Gerald Hengstman (Eindhoven), Rob Haaxma (Paterswolde), Nomdo Jansonius and Lars Rödiger (Groningen), Berit Verbist and Enrico Marani (Leiden), Jan Voogd (Oegstgeest), Maria van Genderen (Zeist), Majid Aramideh (Alkmaar), Henk Berendse and Ysbrand van der Werf (Amsterdam), Harriëtte Verzijl and Dirk Pevernagie (Heeze), Jan Zijlmans (Breda) and Olaf Schijns (Maastricht).

Macroscopical pictures of the brain were kindly provided by Arie Maat (Nijmegen) and most of the MRIs of normal anatomy by Ton van der Vliet (Groningen). Several illustrations were obtained from the Jelgersma Collection of the Anatomical Museum of Leiden University Medical Centre with the help of Andries van Dam. Uğur Türe (Department of Neurosurgery, Yeditepe University Hospital, Istanbul) provided his excellent preparations of long association fibre bundles and Uli Bürgel (Department of Neurosurgery, Antonius Hospital, Kleve) provided several excellent DTIs on these tracts. Other figures were contributed by Martin Cassell (Iowa City), Marcella Brunetti (Chieti) and Thomas Theelen (Nijmegen). Financial support came from the Department of Neurology of the Radboud University Medical Centre (Head: George W.A.M. Padberg), covering part of the costs of the illustrations. Most of the illustrations were made by Ad Gruter (Nieuwegein) and several were contributed by Chris van Huijzen (Nijmegen) and the late Marlu de Leeuw (Nijmegen). Michel Verbruggen (Nijmegen) was invaluable in the processing of the figures. The book contains three general, introductory chapters on the organization and vascularization of the human brain and spinal cord (Chaps. 1 and 2) and on techniques for studying brain circuitry (Chap. 3). Brain circuitry and its disorders are discussed in the chapters on neurofunctional systems: the somatosensory system (Chap. 4), the reticular formation (Chap. 5), the cranial nerves (Chap. 6), the auditory system (Chap. 7), the visual system (Chap. 8), motor systems (Chap. 9), the cerebellum (Chap. 10), the basal ganglia (Chap. 11), the autonomic nervous system (Chap. 12), the hypothalamus and hypothalamohypophysial systems (Chap. 13), the limbic system (Chap. 14) and the cerebral cortex and complex cerebral functions (Chap. 15). The book is intended primarily for neurologists, neuroradiologists and neuropathologists as well as residents in these fields, but may also be useful for all those working in human brain mapping.

Nijmegen, The Netherlands

Hans J. ten Donkelaar

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# Contents

## Chapter 1

### Overview of the Human Brain and Spinal Cord

*Hans J. ten Donkelaar and Anthony H.M. Lohman*

<b>1.1</b>	<b>Introduction</b> .....	1
<b>1.2</b>	<b>Macroscopy of the Brain</b> .....	1
1.2.1	Lateral View of the Brain .....	2
1.2.2	Medial View of the Brain .....	3
1.2.3	Dorsal View of the Brain .....	3
1.2.4	Basal View of the Brain and Its Relations to the Skull Base.....	4
1.2.5	Some Horizontal Sections of the Brain .....	6
1.2.6	Imaging of the Brain.....	6
<b>1.3</b>	<b>The Meninges, the Intracranial Compartments and the Liquor Circulation</b> .....	7
1.3.1	The Meninges .....	7
	Clinical Case 1.1 Epidural, Subdural and Subarachnoid Haemorrhages <i>Antoine Keyser and Pieter Wesseling</i> .....	12
1.3.2	The Intracranial Compartments .....	13
	Clinical Case 1.2 Space-Occupying Lesions <i>Antoine Keyser and Pieter Wesseling</i> .....	13
1.3.3	The Liquor Circulation .....	15
<b>1.4</b>	<b>The Spinal Cord</b> .....	15
1.4.1	Gross Anatomy .....	16
1.4.2	Microscopy: Subdivision of Grey and White Matter .....	17
<b>1.5</b>	<b>The Brain Stem</b> .....	21
1.5.1	The Cranial Nerves .....	21
1.5.2	Three Cross-Sections Through the Brain Stem .....	23
1.5.3	The Reticular Formation and Related Monoaminergic and Cholinergic Nuclei ..	26
<b>1.6</b>	<b>The Cerebellum</b> .....	27
1.6.1	Gross Anatomy, Subdivision and Compartmentalization.....	28
1.6.2	Major Fibre Connections .....	29
1.6.3	Precerebellar Nuclei .....	30
<b>1.7</b>	<b>The Diencephalon</b> .....	30
1.7.1	Subdivision .....	30
1.7.2	The Thalamus and Thalamocortical Connections .....	31
1.7.3	The Hypothalamus.....	35
<b>1.8</b>	<b>The Telencephalon</b> .....	36
1.8.1	Subdivision: Pallium and Subpallium .....	36
1.8.2	Brodmann's and Other Cortical Maps .....	38
1.8.3	Overview of Cortical Connections .....	41
1.8.4	The Limbic System: Rhinencephalon, the Hippocampal Formation and the Amygdala .....	46
1.8.5	The Basal Ganglia and Related Basal Forebrain Structures.....	50
	<b>References</b> .....	54



## Chapter 2

**Vascularization of the Brain and Spinal Cord**

*Hans J. ten Donkelaar, Ton van der Vliet, Anthony H.M. Lohman,  
Antoine Keyser, and Pieter Wesseling*

<b>2.1</b>	<b>Introduction</b> .....	61
<b>2.2</b>	<b>A Few Notes on the Development of the Blood Supply of the Brain</b> .....	62
<b>2.3</b>	<b>Gross Anatomy of the Vessels of the Brain and the Spinal Cord</b> .....	62
<b>2.4</b>	<b>Vascular Imaging</b> .....	65
<b>2.5</b>	<b>Arterial Supply of the Cerebral Cortex</b> .....	68
<b>2.6</b>	<b>The Circle of Willis and Its Perforating Branches</b> .....	70
	Clinical Case 2.1 Aneurysm of the Anterior Communicating Artery <i>Ton van der Vliet</i> .....	74
	Clinical Case 2.2 Aneurysm of the Posterior Communicating Artery <i>Pieter Wesseling</i> .....	75
<b>2.7</b>	<b>Ischaemic Stroke</b> .....	75
	Clinical Case 2.3 MCA Stenosis <i>Lars Rödiger</i> .....	78
	Clinical Case 2.4 Watershed Infarction <i>Ton van der Vliet</i> .....	79
	Clinical Case 2.5 Ischaemic Necrosis in the MCA Territory <i>Pieter Wesseling</i> .....	79
	Clinical Case 2.6 Basilar Tip Aneurysm/Basilar Thrombosis <i>Ton van der Vliet</i> .....	80
<b>2.8</b>	<b>Arterial Supply of the Capsula Interna and the Basal Ganglia</b> .....	82
	Clinical Case 2.7 Small-Vessel Disease of the Lenticulostriate Arteries <i>Peter van Domburg</i> .....	83
<b>2.9</b>	<b>Arterial Supply of the Thalamus</b> .....	84
	Clinical Case 2.8 Thalamic Stroke <i>Ton van der Vliet</i> .....	85
	Clinical Case 2.9 Variants of Paramedian Artery Occlusion <i>Peter van Domburg</i> .....	86
<b>2.10</b>	<b>Arterial Supply of the Cerebellum</b> .....	88
	Clinical Case 2.10 Cerebellar Infarction Due to an Aneurysm of the SCA <i>Ton van der Vliet</i> .....	90
<b>2.11</b>	<b>Arterial Supply of the Brain Stem</b> .....	90
	Clinical Case 2.11 A Typical Wallenberg Syndrome <i>Ton van der Vliet</i> .....	94
	Clinical Case 2.12 Lacunar Infarct of the Pons <i>Peter van Domburg</i> .....	96
<b>2.12</b>	<b>Arterial Supply of the Spinal Cord</b> .....	96
	Clinical Case 2.13 Spinal Cord Infarction Due to a Cervical Tumour <i>Ton van der Vliet</i> .....	97
<b>2.13</b>	<b>Venous Drainage</b> .....	98
	Clinical Case 2.14 V. Galeni Magna Aneurysm <i>Ton van der Vliet</i> .....	101
	Clinical Case 2.15 Sagittal Sinus Thrombosis <i>Ton van der Vliet</i> .....	102
	Clinical Case 2.16: Straight Sinus Thrombosis <i>Peter van Domburg</i> .....	102
	<b>References</b> .....	104

## Chapter 3

**Notes on Techniques***Hans J. ten Donkelaar, Dick Stegeman, and Ton van der Vliet*

<b>3.1</b>	<b>Introduction</b> .....	107
<b>3.2</b>	<b>Tissue-Staining Techniques</b> .....	107
<b>3.3</b>	<b>Tract-Tracing Techniques</b> .....	108
3.3.1	Fibre Dissection.....	108
3.3.2	The Classic Degeneration Techniques.....	109
3.3.3	Modern Tract-Tracing Techniques .....	112
<b>3.4</b>	<b>Immunohistochemical Techniques</b> .....	113
<b>3.5</b>	<b>Electrophysiological Techniques</b> .....	114
3.5.1	EEG and MEG.....	115
3.5.2	Evoked Potentials .....	116
3.5.3	Transcranial Electrical and Magnetic Stimulation .....	117
3.5.4	Electrophysiological Methods for Mapping Brain Motor and Sensory Circuits .....	119
<b>3.6</b>	<b>Non-invasive Imaging Techniques</b> .....	121
3.6.1	MR Imaging.....	122
3.6.2	Diffusion Tensor Imaging.....	123
3.6.3	Functional MRI .....	125
3.6.4	Positron Emission Tomography.....	125
	<b>References</b> .....	126

## Chapter 4

**The Somatosensory System***Hans J. ten Donkelaar, Antoine Keyser, and Peter van Domburg*

<b>4.1</b>	<b>Introduction</b> .....	133
<b>4.2</b>	<b>Receptors and Peripheral Pathways</b> .....	134
4.2.1	Receptors .....	135
4.2.2	Segmental Innervation of the Skin .....	137
	Clinical Case 4.1 Meralgia Paraesthetica <i>Peter van Domburg</i> .....	143
4.2.3	Peripheral Pathways .....	144
	Clinical Case 4.2 Sensory Neuronopathies/Neuropathies <i>Gert van Dijk</i> .....	145
4.2.4	Lesions of the Dorsal Roots .....	146
	Clinical Case 4.3 Neuralgic Amyotrophy <i>Nens van Alfen</i> .....	151
<b>4.3</b>	<b>The Large-Fibred Dorsal (Posterior) Column-Medial Lemniscus Pathway</b> .....	152
4.3.1	Dorsal Column Projections.....	152
	Clinical Case 4.4 Lateral Medullary Lesion Affecting the Decussating Medial Lemniscus <i>Enrico Marani</i> .....	155
4.3.2	Sensory Pathways in the Dorsolateral Funiculus .....	156
4.3.3	The Somatosensory Thalamus.....	157
4.3.4	Somatosensory Cortical Projections.....	159
4.3.5	Sensorimotor Transition .....	164
4.3.6	Lesions of the Dorsal Column-Medial Lemniscus System .....	165
	Clinical Case 4.5 Sensory Effects of Lesions of the Posterior Columns <i>After Gans (1916)</i> .....	167
	Clinical Case 4.6 Lesions of the Medial Lemniscus <i>After Kim (2001)</i> .....	167

	Clinical Case 4.7 The Control of Hand Movements in a Case of Hemianaesthesia Following a Parietal Lesion <i>After Jeannerod et al. (1984)</i> .....	170
	Clinical Case 4.8 Isolated Loss of Stereognosis <i>Peter van Domburg</i> .....	171
<b>4.4</b>	<b>The Small-Fibred Sensory Pathways in the Ventral Quadrant</b> .....	172
4.4.1	The Anterolateral or Pain System.....	172
4.4.1.1	Anterograde Degeneration Studies in Humans .....	172
	Clinical Case 4.9 Distribution of Anterogradely Degenerating Fibres Following Anterolateral Cordotomy <i>After Mehler (1962)</i> .....	173
4.4.1.2	Nociception.....	173
4.4.1.3	The Gate Control Theory.....	173
4.4.1.4	The Spinothalamic Tracts.....	173
4.4.2	Brain Stem Projections .....	178
4.4.3	Thalamic and Hypothalamic Projections.....	180
4.4.4	Cortical Targets.....	181
4.4.5	Descending Pain Modulatory Systems .....	182
4.4.6	Lesions of the Anterolateral System.....	182
	Clinical Case 4.10 Central Neuropathic Pain in Spinal Cord Lesions <i>Peter van Domburg</i> .....	185
	Clinical Case 4.11 Lesions of the Pain System from Medulla to Thalamus <i>Peter van Domburg</i> .....	186
	Clinical Case 4.12 Central Post-stroke Pain Following a Cortical Infarct <i>Peter van Domburg</i> .....	188
<b>4.5</b>	<b>The Trigeminal Somatosensory System</b> .....	189
4.5.1	Trigeminal Afferents.....	189
4.5.2	Brain Stem Trigeminal Sensory Nuclei.....	190
4.5.3	Thalamic Projections .....	192
4.5.4	Cortical Targets.....	193
4.5.5	Lesions of the Trigeminal Somatosensory System.....	193
	Clinical Case 4.13 Trigeminal Neuralgia <i>Peter van Domburg</i> .....	194
	Clinical Case 4.14 Trigeminal Ganglion or Root Compression <i>Peter van Domburg</i> .....	195
	Clinical Case 4.15 Wallenberg Syndrome <i>Peter van Domburg</i> .....	197
	<b>References</b> .....	198

## Chapter 5

### The Reticular Formation and Some Related Nuclei

*Pavel Petrovický, Veronika Němcová, Hans J. ten Donkelaar, Sebastiaan Overeem, and Pieter Vos*

<b>5.1</b>	<b>Introduction</b> .....	211
<b>5.2</b>	<b>Cytoarchitecture, Subdivision and Organization of the Reticular Formation</b> .....	212
5.2.1	The Raphe Nuclei .....	212
5.2.2	The Medial Reticular Formation .....	214
5.2.3	The Lateral Reticular Formation .....	215
<b>5.3</b>	<b>Monoaminergic Nuclei</b> .....	215
5.3.1	Serotonergic Cell Groups .....	215
5.3.2	Noradrenergic Cell Groups.....	216
<b>5.4</b>	<b>Cholinergic Cell Groups</b> .....	216
5.4.1	The Pedunculopontine and Laterodorsal Tegmental Nuclei.....	216

5.4.2	The Basal Nucleus of Meynert and Associated Nuclei .....	218
<b>5.5</b>	<b>Fibre Connections of the Reticular Formation</b> .....	220
<b>5.6</b>	<b>Sleep and Wakefulness</b> .....	223
<b>5.7</b>	<b>Some Sleep Disorders</b> .....	229
	Clinical Case 5.1 Idiopathic Narcolepsy	
	<i>Sebastiaan Overeem</i> .....	230
	Clinical Case 5.2 Symptomatic Narcolepsy	
	<i>Tom Scammell</i> .....	231
	Clinical Case 5.3 Sleep Disturbances in PD	
	<i>Sebastiaan Overeem</i> .....	233
<b>5.8</b>	<b>Disorders of Consciousness</b> .....	234
	Clinical Case 5.4 Uncal Herniation Syndrome	
	<i>Pieter Vos</i> .....	235
	Clinical Case 5.5 Transtentorial Uncal/Tonsillar Herniation	
	<i>Pieter Vos</i> .....	237
	Clinical Case 5.6 “Top of the Basilar” Syndrome	
	<i>Pieter Vos</i> .....	238
	Clinical Case 5.7 High Pontine/Lower Midbrain	
	Lesions Leading to Coma	
	<i>After Parvizi and Damasio (2003)</i> .....	240
	Clinical Case 5.8 Akinetic Mutism	
	<i>Peter van Domburg</i> .....	240
	Clinical Case 5.9 Locked-in Syndrome	
	<i>Pieter Vos</i> .....	242
	<b>References</b> .....	242

## Chapter 6

### The Cranial Nerves

*Hans J. ten Donkelaar, Johannes R.M. Cruysberg, Ton van der Vliet,  
Peter van Domburg, and Willy O. Renier*

<b>6.1</b>	<b>Introduction</b> .....	249
<b>6.2</b>	<b>A Few Notes on the Development of the Brain Stem</b> .....	250
	Clinical Case 6.1 Congenital Cranial Dysinnervation Disorders	
	<i>Johannes R.M. Cruysberg</i> .....	253
<b>6.3</b>	<b>The Oculomotor, Trochlear and Abducens Nerves</b> .....	254
	Clinical Case 6.2 Lesions of Individual Ocular Motor Nerves	
	<i>Johannes R.M. Cruysberg</i> .....	257
	Clinical Case 6.3 Lesions of the Oculomotor Nerve and Nucleus	
	<i>Peter van Domburg</i> .....	261
	Clinical Case 6.4 Sinus Cavemosus Syndromes	
	<i>Peter van Domburg</i> .....	262
<b>6.4</b>	<b>Eye Movements</b> .....	264
6.4.1	Overview.....	264
6.4.2	The Vestibulo-Optokinetic System.....	264
6.4.3	Brain Stem Control of Horizontal and Vertical Eye Movements .....	266
	Clinical Case 6.5 Brain Stem Lesions Affecting Horizontal	
	Eye Movements: INO	
	<i>Peter van Domburg</i> .....	268
	Clinical Case 6.6 Brain Stem Lesions Affecting Vertical Eye Movements:	
	Parinaud Syndrome	
	<i>Peter van Domburg</i> .....	269
6.4.4	Voluntary Control of Eye Movements.....	270
	Clinical Case 6.7 Paralysis of Saccades and Pursuit	
	<i>Martin Lammens</i> .....	271

<b>6.5</b>	<b>The Trigeminal Nerve</b> .....	272
6.5.1	The Sensory Part of the Trigeminal Nerve.....	272
	Clinical Case 6.8 Trigeminal Neuralgia	
	<i>Peter van Domburg</i> .....	274
6.5.2	The Motor Part of the Trigeminal Nerve.....	274
	Clinical Case 6.9 Late Blink Reflex Changes in Lateral Medullary Lesions	
	<i>Majid Aramideh</i> .....	277
<b>6.6</b>	<b>The Facial Nerve</b> .....	279
	Clinical Case 6.10 Facial Nerve Paralysis	
	<i>Willy O. Renier</i> .....	280
	Clinical Case 6.11 Congenital Facial Palsy	
	<i>Harriëtte Verzijl and Martin Lammens</i> .....	281
<b>6.7</b>	<b>The Gustatory System</b> .....	283
<b>6.8</b>	<b>The Vestibulocochlear Nerve</b> .....	284
6.8.1	The Vestibular Nerve and Nuclei.....	287
6.8.2	Fibre Connections of the Vestibular Nuclei.....	287
6.8.3	Functional and Pathophysiological Aspects of Vestibular Control.....	288
	Clinical Case 6.12 Peripheral Vestibular Disorders	
	<i>Myrthe Hol</i> .....	290
	Clinical Case 6.13 Central Vestibular Disorders	
	<i>After Dieterich et al. (2005)</i> .....	292
<b>6.9</b>	<b>The Glossopharyngeal, Vagal and Accessory Cranial Nerves</b> .....	293
6.9.1	The IXth, Xth and XIth Cranial Nerves.....	293
	Clinical Case 6.14 Lesions of the IXth, Xth and XIth Cranial Nerves	
	<i>Willy O. Renier</i> .....	294
6.9.2	Swallowing.....	295
	Clinical Case 6.15 Dysphagia	
	<i>Peter van Domburg</i> .....	296
<b>6.10</b>	<b>The Hypoglossal Nerve</b> .....	297
	Clinical Case 6.16 Hypoglossal Paresis	
	<i>Willy O. Renier</i> .....	298
	<b>References</b> .....	298

## Chapter 7

### The Auditory System

*Hans J. ten Donkelaar and Kimitaka Kaga*

<b>7.1</b>	<b>Introduction</b> .....	305
<b>7.2</b>	<b>The Cochlea and the Cochlear Nerve</b> .....	306
7.2.1	The Middle Ear and the Cochlea: Mechanical Transmission of Sound.....	306
7.2.2	Cochlear Hair Cells: Transduction and Amplification.....	308
7.2.3	Spiral Ganglion Cells and the Cochlear Nerve: Neural Transmission.....	308
7.2.4	The Auditory Periphery: Generation of Evoked Activity.....	308
7.2.5	Hearing Loss.....	309
	Clinical Case 7.1 Cerebellopontine Angle Tumour	
	<i>Kimitaka Kaga</i> .....	310
<b>7.3</b>	<b>The Brain Stem Auditory System</b> .....	312
7.3.1	The Cochlear Nuclei: Diversification of Cochlear Input.....	312
7.3.2	The Superior Olivary Complex: Recreation of Auditory Space.....	313
7.3.3	The Upper Brain Stem: Integration of Ascending Auditory Pathway.....	313
7.3.4	Brain Stem Topography: Generation of Evoked Potentials.....	314
	Clinical Case 7.2 Impaired Sound Localization Following	
	a Midline Pontine Lesion	
	<i>After Levine and Häusler (2001)</i> .....	314
<b>7.4</b>	<b>The Forebrain Auditory System</b> .....	315
7.4.1	The Auditory Thalamus.....	315
7.4.2	The Acoustic Radiation.....	315
7.4.3	The Auditory Cortex: Sequential Levels of Auditory Processing.....	316

7.4.4	Auditory Disorders Related to Stroke .....	319
	Clinical Case 7.3 Auditory Agnosia Caused by Bilateral Lesions Restricted to the Auditory Radiations	
	<i>Kimitaka Kaga</i> .....	321
	Clinical Case 7.4 Neuropathology of Auditory Agnosia Following Bilateral Temporal Lobe Infarction	
	<i>Kimitaka Kaga</i> .....	322
	Clinical Case 7.5 Auditory Hallucinations Following a Metastasis in Heschl's Gyrus	
	<i>Peter van Domburg</i> .....	324
<b>7.5</b>	<b>The Descending Auditory System</b> .....	325
	<b>References</b> .....	326
Chapter 8		
<b>The Visual System</b>		
<i>Hans J. ten Donkelaar and Johannes R.M. Cruysberg</i>		
<b>8.1</b>	<b>Introduction</b> .....	331
<b>8.2</b>	<b>Anatomy and Imaging of the Visual System</b> .....	332
8.2.1	The Retina .....	332
	Clinical Case 8.1 Hereditary Retinal Dystrophies	
	<i>Johannes R.M. Cruysberg</i> .....	335
8.2.2	The Optic Nerve, the Optic Chiasm and the Optic Tract .....	336
	Clinical Case 8.2 Isolated Absence of the Optic Chiasm	
	<i>Nomdo Jansonius and Ton van der Vliet</i> .....	338
8.2.3	The Lateral Geniculate Body.....	338
	Clinical Case 8.3 Selective Transneuronal Degeneration of the LGB After Enucleation	
	<i>Akira Hori</i> .....	339
8.2.4	The Optic Radiation .....	341
8.2.5	The Superior Colliculus and the Pulvinar .....	341
8.2.6	The Pretectum and the Pupillary Light Reflex .....	343
	Clinical Case 8.4 Lesions of the Pupillary Light Reflex Pathway	
	<i>Maria van Genderen and Johannes R.M. Cruysberg</i> .....	345
	Clinical Case 8.5 Horner Syndrome	
	<i>Johannes R.M. Cruysberg</i> .....	346
<b>8.3</b>	<b>The Visual Cortex</b> .....	346
8.3.1	The Striate Cortex.....	346
	Clinical Case 8.6 MELAS and Central Blindness	
	<i>Michèl Willemsen</i> .....	349
8.3.2	Extrastriate and Visual Association Cortices.....	349
<b>8.4</b>	<b>The Retinogeniculocortical Pathway and Typical Visual-Field Defects</b> .....	351
	Clinical Case 8.7 The Spectrum of Visual-Field Defects	
	<i>Johannes R.M. Cruysberg</i> .....	353
	Clinical Case 8.8 Altitudinal Hemianopia	
	<i>Martin Lammens</i> .....	355
<b>8.5</b>	<b>The Extrastriate Visual Cortex and Abnormalities of Complex Visual Perception</b> .....	356
8.5.1	Dorsal Pathway Lesions .....	357
	Clinical Case 8.9 Bálint Syndrome	
	<i>Ton van der Vliet</i> .....	357
8.5.2	Ventral Pathway Lesions .....	358
	Clinical Case 8.10 Cerebral Achromatopsia	
	<i>Johannes R.M. Cruysberg and Antoine Keyser</i> .....	359
	Clinical Case 8.11 Paroxysmal Visual Phenomena	
	<i>Peter van Domburg</i> .....	360
	<b>References</b> .....	361

## Chapter 9

**Motor Systems**

Hans J. ten Donkelaar

<b>9.1</b>	<b>Introduction</b> .....	367
<b>9.2</b>	<b>The Peripheral Motor System</b> .....	368
9.2.1	The Peripheral or LMNs.....	368
9.2.2	Motor Units and Muscle Units .....	370
9.2.3	Motor Unit–Muscle Unit Association .....	372
9.2.4	Reflex Pathways in the Spinal Cord .....	374
	Clinical Case 9.1 Manual Motor Control in a Deafferented Man	
	<i>John Rothwell</i> .....	376
9.2.5	Muscle Tone .....	377
9.2.6	Lesions of Peripheral Motoneurons.....	378
9.2.6.1	Plexus Lesions .....	378
9.2.6.2	Diseases of the Motor Unit.....	379
9.2.6.3	Motoneuron Disease.....	380
	Clinical Case 9.2 Lesions of the Brachial Plexus	
	<i>Antoine Keyser</i> .....	381
	Clinical Case 9.3 Diabetic Lumbosacral Plexus Neuropathy	
	<i>Nens van Alfen</i> .....	382
<b>9.3</b>	<b>Gait and Posture</b> .....	382
	Clinical Case 9.4 Atrophy of Intrinsic Hand Muscles in Patients	
	with Parietal Lesions	
	<i>After Op de Coul (1970)</i> .....	383
	Clinical Case 9.5 The Spectrum of MND	
	<i>Jurgen Schelhaas and Benno Küsters</i> .....	385
	Clinical Case 9.6 A Juvenile ALS Case	
	<i>Jan Geelen, Willy O. Renier and Henk ter Laak</i> .....	386
9.3.1	Physiological Basis of Human Locomotion .....	388
9.3.2	Afferent Control .....	389
9.3.3	Supraspinal Control .....	389
9.3.4	Spinal Cord Injuries.....	391
	Clinical Case 9.7 The Brown–Séquad Syndrome	
	<i>Antoine Keyser</i> .....	392
9.3.5	Gait Disorders.....	393
	Clinical Case 9.8 Gait Disorders	
	<i>Peter van Domburg</i> .....	394
9.3.6	Posture .....	395
<b>9.4</b>	<b>Central Control of Movement</b> .....	396
9.4.1	Descending Pathways to the Spinal Cord.....	396
9.4.2	Long Corticofugal Pathways .....	401
9.4.2.1	Corticobulbar Fibres .....	401
	Clinical Case 9.9 Corticobulbar Projections	
	<i>After Kuypers (1958)</i> .....	402
	Clinical Case 9.10 Aberrant Corticofacial	
	Projections	
	<i>Peter Urban</i> .....	404
9.4.2.2	The Internal Capsule.....	406
9.4.2.3	The Corticospinal Tract .....	406
	Clinical Case 9.11 Course and Site of Termination	
	of Corticospinal Projections	
	<i>After Schoen (1969)</i> .....	412
9.4.2.4	Indirect Corticospinal Projections .....	414
	Clinical Case 9.12 Interruption of a Relay of Corticospinal	
	Excitation by a Spinal Lesion at C6–C7	
	<i>Emmanuel Pierrot-Deseilligny</i> .....	415