## Contents

*Preface* xiii  
*About the companion website* xv  

### Chapter 1  Introduction to the Nervous System 1  
1.1 Neurons 1  
   1.1.1 Neuronal Cell Body (Soma) 2  
   1.1.2 Axon Hillock 3  
   1.1.3 Neuronal Processes – Axons and Dendrites 3  
1.2 Classification of Neurons 4  
   1.2.1 Neuronal Classification by Function 4  
   1.2.2 Neuronal Classification by Number of Processes 4  
1.3 The Synapse 5  
   1.3.1 Components of a Synapse 5  
   1.3.2 Neurotransmitters and Neuromodulators 5  
   1.3.3 Neuronal Plasticity 6  
   1.3.4 The Neuropil 6  
1.4 Neuroglial Cells 6  
   1.4.1 Neuroglial Cells Differ from Neurons 6  
   1.4.2 Identification of Neuroglia 6  
   1.4.3 Neuroglial Function 8  
   1.4.4 Neuroglial Cells and Aging 9  
   1.4.5 Neuroglial Cells and Brain Tumors 9  
1.5 Axonal Transport 9  
   1.5.1 Functions of Axonal Transport 9  
   1.5.2 Defective Axonal Transport 9  
1.6 Degeneration and Regeneration 10  
   1.6.1 Axon or Retrograde Reaction 10  
   1.6.2 Anterograde Degeneration 11  
   1.6.3 Retrograde Degeneration 11  
   1.6.4 Regeneration of Peripheral Nerves 11  
   1.6.5 Regeneration and Neurotrophic Factors 13  
   1.6.6 Regeneration in the Central Nervous System 13  
1.7 Neural Transplantation 14  
   Further Reading 14  

### Chapter 2  Development of the Nervous System 17  
2.1 First Week 19  
   2.1.1 Fertilization 19  
   2.1.2 From Two Cells to the Free Blastocyst 19  
2.2 Second Week 20  
   2.2.1 Implantation and Two Distinct Layers of Cells 20  
   2.2.2 Primitive Streak and a Third Layer of Cells 20  
2.3 Third Week 20  
   2.3.1 Primitive Node and Notochordal Process 20  
   2.3.2 Neural Plate, Groove, Folds, and Neuromeres 21  
   2.3.3 Three Main Divisions of the Brain 21  
   2.3.4 Mesencephalic Flexure Appears 21  
2.4 Fourth Week 21  
   2.4.1 Formation of the Neural Tube 21  
   2.4.2 Rostral and Caudal Neuropores Open 22  
   2.4.3 Neural Crest Cells Emerge 23  
   2.4.4 Neural Canal – the Future Ventricular System 24  
   2.4.5 Neuropores Close and the Neural Tube Forms 24  
   2.4.6 Cervical Flexure Present 24  
2.5 Fifth Week 24  
   2.5.1 Simple Tube, Complex Transformation 24  
   2.5.2 Five Subdivisions of the Brain Appear 24  
   2.5.3 Brain Vesicles Versus Brain Regions 25  
2.6 Vulnerability of the Developing Nervous System 26  
2.7 Congenital Malformations of the Nervous System 27  
   2.7.1 Spinal Dysraphism 27  
   2.7.2 Anencephaly 28  
   2.7.3 Microcephaly 28  
   Further Reading 29  

### Chapter 3  The Spinal Cord 31  
3.1 Embryological Considerations 31  
   3.1.1 Layers of the Developing Spinal Cord 31  
   3.1.2 Formation of Ventral Gray Columns and Ventral Roots 32  
   3.1.3 Formation of Dorsal Gray Columns 32  
   3.1.4 Dorsal and Ventral Horns Versus Dorsal and Ventral Gray Columns 33  
   3.1.5 Development of Neural Crest Cells 33  
   3.1.6 Framework of the Adult Cord is Present at Birth 34  
3.2 Gross Anatomy 34  
   3.2.1 Spinal Cord Weight and Length 34  
   3.2.2 Spinal Segments, Regions, and Enlargements 34  
   3.2.3 Spinal Segments in Each Region Are of Unequal Length 34  
   3.2.4 Conus Medullaris, Filum Terminale, and Cauda Equina 35  
   3.2.5 Termination of the Adult Spinal Cord 35  
   3.2.6 Differential Rate of Growth: Vertebral Column Versus the Spinal Cord 36  
   3.2.7 Relationship Between Spinal Segments and Vertebræ 37  
3.3 Nuclear Groups – Gray Matter 37  
   3.3.1 General Arrangement of Spinal Cord Gray Matter 37  
   3.3.2 Gray Matter at Enlargement Levels 37  
   3.3.3 Spinal Laminae 38
7.4 Path for Superficial Pain and Thermal Extremes from the Head 108
7.4.1 Modalities and Receptors 108
7.4.2 Primary Neurons 108
7.4.3 Secondary Neurons 110
7.4.4 Thalamic Neurons 111
7.5 Path for Thermal Discrimination from the Head 111
7.5.1 Modality and Receptors 111
7.5.2 Primary Neurons 111
7.5.3 Secondary Neurons 111
7.5.4 Thalamic Neurons 112
7.5.5 Cortical Neurons 112
7.6 Somatic Afferent Components of VII, IX, and X 113
7.7 Trigeminal Neuralgia 113
7.7.1 Causes of Trigeminal Neuralgia 113
7.7.2 Methods of Treatment for Trigeminal Neuralgia 113
7.8 Glossopharyngeal Neuralgia 114
Further Reading 114

Chapter 8 Paths for Touch, Pressure, Proprioception, and Vibration 117
8.1 Path for General Tactile Sensation from the Body 117
8.1.1 Modalities and Receptors 117
8.1.2 Primary Neurons 118
8.1.3 Secondary Neurons 118
8.1.4 Thalamic Neurons 120
8.2 Path for Tactile Discrimination, Pressure, Proprioception, and Vibration from the Body 120
8.2.1 Modalities and Receptors 120
8.2.2 Primary Neurons 123
8.2.3 Secondary Neurons 124
8.2.4 Thalamic Neurons 126
8.2.5 Cortical Neurons 127
8.2.6 Spinal Cord Stimulation for the Relief of Pain 129
8.3 Path for Tactile Discrimination from the Head 130
8.3.1 Modalities and Receptors 130
8.3.2 Primary Neurons 130
8.3.3 Secondary Neurons 130
8.3.4 Thalamic Neurons 130
8.3.5 Cortical Neurons 130
8.4 Path for General Tactile Sensation from the Head 131
8.4.1 Modalities and Receptors 131
8.4.2 Primary Neurons 131
8.4.3 Secondary Neurons 132
8.4.4 Thalamic Neurons 132
8.4.5 Cortical Neurons 132
8.5 Path for Proprioception, Pressure, and Vibration from the Head 133
8.5.1 Modalities and Receptors 133
8.5.2 Primary Neurons 133
8.5.3 Secondary Neurons 134
8.5.4 Thalamic Neurons 134
8.5.5 Cortical Neurons 135
8.6 Trigeminal Motor Component 135
8.7 Certain Trigeminal Reflexes 136
8.7.1 "Jaw-Closing" Reflex 136
8.7.2 Corneal Reflex 137
Further Reading 138

Chapter 9 The Reticular Formation 141
9.1 Structural Aspects 141
9.1.1 Reticular Nuclei in the Medulla 142
9.1.2 Reticular Nuclei in the Pons 143
9.1.3 Reticular Nuclei in the Midbrain 145
9.2 Ascending Reticular System 146
9.3 Descending Reticular System 149
9.4 Functional Aspects of the Reticular Formation 149
9.4.1 Consciousness 150
9.4.2 Homeostatic Regulation 151
9.4.3 Visceral Reflexes 152
9.4.4 Motor Function 153
Further Reading 153

Chapter 10 The Auditory System 155
10.1 Gross Anatomy 155
10.1.1 External Ear 155
10.1.2 Middle Ear 155
10.1.3 Internal Ear 156
10.2 The Ascending Auditory Path 158
10.2.1 Modality and Receptors 158
10.2.2 Primary Neurons 159
10.2.3 Secondary Neurons 159
10.2.4 Tertiary Neurons 161
10.2.5 Inferior Collicular Neurons 161
10.2.6 Thalamic Neurons 161
10.2.7 Cortical Neurons 161
10.2.8 Comments 164
10.3 Descending Auditory Connections 164
10.3.1 Electrical Stimulation of Cochlear Efferents 165
10.3.2 Autonomic Fibers to the Cochlea 165
10.4 Injury to the Auditory Path 166
10.4.1 Congenital Loss of Hearing 166
10.4.2 Decoupling of Stereocilia 166
10.4.3 Tinnitus 166
10.4.4 Noise-Induced Loss of Hearing 166
10.4.5 Aging and the Loss of Hearing 166
10.4.6 Unilateral Loss of Hearing 166
10.4.7 Injury to the Inferior Colliculi 166
10.4.8 Unilateral Injury to the Medial Geniculate Body or Auditory Cortex 166
10.4.9 Bilateral Injury to the Primary Auditory Cortex 167
10.4.10 Auditory Seizures – Audenes 167
10.5 Cochlear Implants 167
10.6 Auditory Brain Stem Implants 167
Further Reading 167

Chapter 11 The Vestibular System 171
11.1 Gross Anatomy 171
11.1.1 Internal Ear 171
## CONTENTS

<table>
<thead>
<tr>
<th>Chapter</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>11.2 The Ascending Vestibular Path</td>
<td>173</td>
</tr>
<tr>
<td>11.2.1 Modalities and Receptors</td>
<td>173</td>
</tr>
<tr>
<td>11.2.2 Primary Neurons</td>
<td>175</td>
</tr>
<tr>
<td>11.2.3 Secondary Neurons</td>
<td>177</td>
</tr>
<tr>
<td>11.2.4 Thalamic Neurons</td>
<td>179</td>
</tr>
<tr>
<td>11.2.5 Cortical Neurons</td>
<td>179</td>
</tr>
<tr>
<td>11.3 Other Vestibular Connections</td>
<td>180</td>
</tr>
<tr>
<td>11.3.1 Primary Vestibulocerebellar Fibers</td>
<td>181</td>
</tr>
<tr>
<td>11.3.2 Vestibular Nuclear Projections to Nuclei of the Extraocular Muscles</td>
<td>182</td>
</tr>
<tr>
<td>11.3.3 Vestibular Nuclear Projections to the Reticular Formation</td>
<td>182</td>
</tr>
<tr>
<td>11.3.4 Vestibular Projections to the Contra lateral Vestibular Nuclei</td>
<td>182</td>
</tr>
<tr>
<td>11.3.5 Other Vestibular Connections</td>
<td>182</td>
</tr>
<tr>
<td>11.4 The Efferent Component of the Vestibular System</td>
<td>182</td>
</tr>
<tr>
<td>11.5 Afferent Projections to the Vestibular Nuclei</td>
<td>182</td>
</tr>
<tr>
<td>11.6 Vertigo</td>
<td>183</td>
</tr>
<tr>
<td>11.6.1 Physiological Vertigo</td>
<td>183</td>
</tr>
<tr>
<td>11.6.2 Pathological Vertigo</td>
<td>183</td>
</tr>
<tr>
<td>11.6.3 Vertigo</td>
<td>184</td>
</tr>
<tr>
<td>Further Reading</td>
<td></td>
</tr>
<tr>
<td>Chapter 12 The Visual System</td>
<td>187</td>
</tr>
<tr>
<td>12.1 Retina</td>
<td></td>
</tr>
<tr>
<td>12.1.1 Pigmented Layer</td>
<td>187</td>
</tr>
<tr>
<td>12.1.2 Neural Layer</td>
<td>187</td>
</tr>
<tr>
<td>12.1.3 Other Retinal Elements</td>
<td>188</td>
</tr>
<tr>
<td>12.1.4 Special Retinal Regions</td>
<td>189</td>
</tr>
<tr>
<td>12.1.5 Retinal Areas</td>
<td>190</td>
</tr>
<tr>
<td>12.1.6 Visual Fields</td>
<td>190</td>
</tr>
<tr>
<td>12.2 Visual Path</td>
<td>191</td>
</tr>
<tr>
<td>12.2.1 Receptors</td>
<td>191</td>
</tr>
<tr>
<td>12.2.2 Primary Retinal Neurons</td>
<td>193</td>
</tr>
<tr>
<td>12.2.3 Secondary Retinal Neurons</td>
<td>193</td>
</tr>
<tr>
<td>12.2.4 Optic Nerve [II]</td>
<td>194</td>
</tr>
<tr>
<td>12.2.5 Optic Chiasm</td>
<td>196</td>
</tr>
<tr>
<td>12.2.6 Optic Tract</td>
<td>197</td>
</tr>
<tr>
<td>12.2.7 Thalamic Neurons</td>
<td>197</td>
</tr>
<tr>
<td>12.2.8 Optic Radiations</td>
<td>198</td>
</tr>
<tr>
<td>12.2.9 Cortical Neurons</td>
<td>198</td>
</tr>
<tr>
<td>12.3 Injuries to the Visual System</td>
<td>200</td>
</tr>
<tr>
<td>12.3.1 Retinal Injuries</td>
<td>200</td>
</tr>
<tr>
<td>12.3.2 Injury to the Optic Nerve</td>
<td>201</td>
</tr>
<tr>
<td>12.3.3 Injuries to the Optic Chiasm</td>
<td>201</td>
</tr>
<tr>
<td>12.3.4 Injuries to the Optic Tract</td>
<td>202</td>
</tr>
<tr>
<td>12.3.5 Injury to the Lateral Geniculate Body</td>
<td>202</td>
</tr>
<tr>
<td>12.3.6 Injuries to the Optic Radiations</td>
<td>202</td>
</tr>
<tr>
<td>12.3.7 Injuries to the Visual Cortex</td>
<td>203</td>
</tr>
<tr>
<td>Further Reading</td>
<td>204</td>
</tr>
<tr>
<td>Chapter 13 Ocular Movements and Visual Reflexes</td>
<td>207</td>
</tr>
<tr>
<td>13.1 Ocular Movements</td>
<td>207</td>
</tr>
<tr>
<td>13.1.1 Primary Position of the Eyes</td>
<td>207</td>
</tr>
<tr>
<td>13.2 Conjugate Ocular Movements</td>
<td>207</td>
</tr>
<tr>
<td>13.2.1 Miniature Ocular Movements</td>
<td>208</td>
</tr>
<tr>
<td>13.2.2 Saccades</td>
<td>208</td>
</tr>
<tr>
<td>13.2.3 Smooth Pursuit Movements</td>
<td>209</td>
</tr>
<tr>
<td>13.2.4 Vestibular Movements</td>
<td>209</td>
</tr>
<tr>
<td>13.3 Extraocular Muscles</td>
<td>209</td>
</tr>
<tr>
<td>13.4 Innervation of the Extraocular Muscles</td>
<td>210</td>
</tr>
<tr>
<td>13.4.1 Abducent Nucleus and Nerve</td>
<td>211</td>
</tr>
<tr>
<td>13.4.2 Trochlear Nucleus and Nerve</td>
<td>211</td>
</tr>
<tr>
<td>13.5 Anatomical Basis of Conjugate Ocular Movements</td>
<td>215</td>
</tr>
<tr>
<td>13.6 Medial Longitudinal Fasciculus</td>
<td>216</td>
</tr>
<tr>
<td>13.7 Vertical Ocular Movements</td>
<td>216</td>
</tr>
<tr>
<td>13.10 Vestibular Connections and Ocular Movements</td>
<td>216</td>
</tr>
<tr>
<td>13.11 Congenital Nystagmus</td>
<td>219</td>
</tr>
<tr>
<td>13.12 Orbital Bobbing</td>
<td>219</td>
</tr>
<tr>
<td>13.13 Examination of the Visual System</td>
<td>219</td>
</tr>
<tr>
<td>13.14 Visual Reflexes</td>
<td>221</td>
</tr>
<tr>
<td>13.14.1 The Light Reflex</td>
<td>221</td>
</tr>
<tr>
<td>13.14.2 The Near Reflex</td>
<td>222</td>
</tr>
<tr>
<td>13.14.3 Pupillary Dilatation</td>
<td>223</td>
</tr>
<tr>
<td>13.14.4 The Lateral Tectotegmentospinal Tract</td>
<td>223</td>
</tr>
<tr>
<td>13.14.5 The Spinotectal Tract</td>
<td>223</td>
</tr>
<tr>
<td>13.14.6 The Afferent Pupillary Defect</td>
<td>225</td>
</tr>
<tr>
<td>Further Reading</td>
<td>225</td>
</tr>
<tr>
<td>Chapter 14 The Thalamus</td>
<td>227</td>
</tr>
<tr>
<td>14.1 Introduction</td>
<td>227</td>
</tr>
<tr>
<td>14.2 Nuclear Groups of the Thalamus</td>
<td>228</td>
</tr>
<tr>
<td>14.2.1 Anterior Nuclei and the Lateral Dorsal Nucleus</td>
<td>229</td>
</tr>
<tr>
<td>14.2.2 Intralaminar Nuclei</td>
<td>231</td>
</tr>
<tr>
<td>14.2.3 Medial Nuclei</td>
<td>233</td>
</tr>
<tr>
<td>14.2.4 Median Nuclei</td>
<td>233</td>
</tr>
<tr>
<td>14.2.5 Metathalamic Body and Nuclei</td>
<td>234</td>
</tr>
<tr>
<td>14.2.6 Posterior Nuclear Complex</td>
<td>235</td>
</tr>
<tr>
<td>14.2.7 Pulvinar Nuclei and Lateral Posterior Nucleus</td>
<td>235</td>
</tr>
<tr>
<td>14.2.8 Reticular Nucleus</td>
<td>235</td>
</tr>
<tr>
<td>14.2.9 Ventral Nuclei</td>
<td>236</td>
</tr>
<tr>
<td>14.3 Injuries to the Thalamus</td>
<td>238</td>
</tr>
<tr>
<td>14.4 Mapping the Human Thalamus</td>
<td>238</td>
</tr>
<tr>
<td>14.5 Stimulation of the Human Thalamus</td>
<td>239</td>
</tr>
<tr>
<td>14.6 The Thalamus as a Neurosurgical Target</td>
<td>239</td>
</tr>
<tr>
<td>Further Reading</td>
<td>240</td>
</tr>
<tr>
<td>Chapter 15 Lower Motor Neurons and the Pyramidal System</td>
<td>243</td>
</tr>
<tr>
<td>15.1 Regions Involved in Motor Activity</td>
<td>243</td>
</tr>
<tr>
<td>15.2 Lower Motor Neurons</td>
<td>243</td>
</tr>
<tr>
<td>15.2.1 Terms Related to Motor Activity</td>
<td>243</td>
</tr>
<tr>
<td>15.2.2 Lower Motor Neurons in the Spinal Cord</td>
<td>244</td>
</tr>
</tbody>
</table>
Chapter 15  The Motor System

15.2.3 Activation of Motor Neurons 245
15.2.4 Lower Motor Neurons in the Brain Stem 245
15.2.5 Injury to Lower Motor Neurons 246
15.2.6 Example of a Lower Motor Neuron Disorder 247

15.3 Pyramidal System

15.3.1 Corticospinal Component 247
15.3.2 Corticobulbar Component 252
15.3.3 Clinical Neuroanatomical Correlation 255

Further Reading 256

Chapter 16  The Extrapyramidal System and Cerebellum

16.1 Extrapyramidal System

16.1.1 Extrapyramidal Motor Areas 260
16.1.2 Basal Ganglia (Basal Nuclei) 260
16.1.3 Afferents to the Basal Ganglia 265
16.1.4 Cortical–Striatal–Pallidal–Thalamic–Cortical Circuits 266
16.1.5 Multisynaptic Descending Paths 266
16.1.6 Common Discharge Paths 267
16.1.7 Somatotopic Organization of the Basal Ganglia 267

16.2 Cerebellum

16.2.1 External Features of the Cerebellum 267
16.2.2 Cerebellar Cortex 270
16.2.3 Deep Cerebellar Nuclei 271
16.2.4 Cerebellar White Matter 271

16.3 Input to the Cerebellum Through the Peduncles 271

16.3.1 Inferior Cerebellar Peduncle (ICP) 271
16.3.2 Middle Cerebellar Peduncle (MCP) 272
16.3.3 Superior Cerebellar Peduncle (SCP) 272

16.4 Input to the Cerebellum 272

16.4.1 Incoming Fibers to the Cerebellum 272
16.4.2 Cerebellar Output 273

16.5 Cerebellar Output

16.5.1 From the Fastigial Nuclei 273
16.5.2 From the Globus and Emboliform Nuclei 273
16.5.3 From the Dentate Nuclei 273

16.6 Cerebellar Circuitry 273
16.7 Common Discharge Paths 273
16.8 Cerebellar Functions

16.8.1 Motor Functions 274
16.8.2 Nonmotor Functions 274
16.8.3 Studies Involving the Human Cerebellum 274
16.8.4 Localization in the Cerebellum 274

16.9 Manifestations of Injuries to the Motor System

16.9.1 Injury to the Premotor Cortex 275
16.9.2 Injury to the Basal Ganglia 275
16.9.3 Injury to, or Deep Brain Stimulation of, the Subthalamic Nucleus 276
16.9.4 Injury to the Cerebellum 277
16.9.5 Localization of Cerebellar Damage 278

16.10 Decorticate Versus Decerebrate Rigidity

16.10.1 Decerebrate Rigidity 278
16.10.2 Decorticate Rigidity 278

Further Reading 278

Chapter 17  The Olfactory and Gustatory Systems

17.1 The Olfactory System

17.1.1 Receptors 283
17.1.2 Primary Neurons 284
17.1.3 Olfactory Fila and the Olfactory Nerve 284
17.1.4 Olfactory Bulb – Secondary Neurons 285
17.1.5 Olfactory Tract 285
17.1.6 Medial Stria 285
17.1.7 Lateral Stria 285
17.1.8 Thalamic Neurons 288
17.1.9 Cortical Neurons 288
17.1.10 Efferent Olfactory Connections 288
17.1.11 Injuries to the Olfactory System 288

17.2 The Gustatory System

17.2.1 Receptors 290
17.2.2 Primary Neurons 292
17.2.3 Secondary Neurons 293
17.2.4 The Ascending Gustatory Path 293
17.2.5 Thalamic Neurons 293
17.2.6 Cortical Neurons 293
17.2.7 Injuries to the Gustatory System 294

Further Reading 295
## Chapter 19  The Hypothalamus  313

19.1 Hypothalamic Zones (Medial to Lateral) 313  
19.2 Hypothalamic Regions (Anterior to Posterior) 315  
19.3 Hypothalamic Nuclei  
\[19.3.1\] Chiasmal Region 315  
\[19.3.2\] Tuberal Region 319  
\[19.3.3\] Mamillary Region 320  
19.4 Fiber Connections  
\[19.4.1\] Medial Forebrain Bundle 321  
\[19.4.2\] Stria Terminalis 321  
\[19.4.3\] Fornix 321  
\[19.4.4\] Diencephalic Periventricular System 321  
\[19.4.5\] Dorsal Longitudinal Fasciculus 321  
\[19.4.6\] Anterior and Posterior Hypothalamotegmental Tracts 322  
\[19.4.7\] Pallidohypothalamic Tract 322  
\[19.4.8\] Mamillothalamic Tract 322  
\[19.4.9\] Vascular Connections 322  
19.5 Functions of the Hypothalamus  
\[19.5.1\] Water Balance – Water Intake and Loss 322  
\[19.5.2\] Eating – Food Intake 322  
\[19.5.3\] Temperature Regulation 323  
\[19.5.4\] Autonomic Regulation 323  
\[19.5.5\] Emotional Expression 323  
\[19.5.6\] Wakefulness and Sleep – Biological Rhythms 323  
\[19.5.7\] Control of the Endocrine System 324  
\[19.5.8\] Reproduction 324  
Further Reading 324

## Chapter 20  The Autonomic Nervous System  327

20.1 Historical Aspects 327  
20.2 Structural Aspects  
\[20.2.1\] Location of Autonomic Neurons of Origin 328  
\[20.2.2\] Manner of Distribution of Autonomic Fibers 329  
\[20.2.3\] Termination of Autonomic Fibers 330  
20.3 Somatic Efferents Versus Visceral Efferents 331  
20.4 Visceral Afferents 331  
20.5 Regulation of the Autonomic Nervous System 332  
20.6 Disorders of the Autonomic Nervous System 333  
Further Reading 334

## Chapter 21  The Cerebral Hemispheres  337

21.1 Facts and Figures 337  
21.2 Cortical Neurons 338  
21.3 Cortical Layers 338  
21.4 Cortical Columns (Microarchitecture) 343  
21.5 Functional Aspects of the Cerebral Cortex 343  
21.6 Cerebral Dominance, Lateralization, and Asymmetry 343  
21.7 Frontal Lobe  
\[21.7.1\] Primary Motor Cortex 343  
\[21.7.2\] Premotor Cortex 344  
\[21.7.3\] Supplementary Motor Area (SMA) 345  
\[21.7.4\] Cingulate Motor Areas 345  
\[21.7.5\] Frontal Eye Fields 345  
\[21.7.6\] Broca’s Area 346  
\[21.7.7\] Prefrontal Cortex 346  
21.8 Parietal Lobe  
\[21.8.1\] Primary Somatosensory Cortex (SI) 347  
\[21.8.2\] Secondary Somatosensory Cortex (SII) 350  
\[21.8.3\] Superior Parietal Lobule 350  
\[21.8.4\] Inferior Parietal Lobule 352  
\[21.8.5\] Parietal Vestibular Cortex (2v) 352  
\[21.8.6\] Mirror Representation of Others’ Actions 353  
\[21.8.7\] Preoccipital Areas 353  
21.9 Occipital Lobe 354  
\[21.9.1\] Primary Visual Cortex (V1) 354  
\[21.9.2\] Secondary Visual Cortex 354  
21.10 Temporal Lobe 354  
\[21.10.1\] Primary Auditory Cortex (AI) 354  
\[21.10.2\] Wernicke’s Area 354  
\[21.10.3\] Temporal Vestibular Cortex 355  
\[21.10.4\] Midtemporal Areas Related to Memory 356  
\[21.10.5\] Anomia 356  
\[21.10.6\] Prosopagnosia 356  
\[21.10.7\] Psychomotor Seizures 356  
21.11 Insula 357  
21.12 Aphasia 358  
\[21.12.1\] Broca’s Aphasia 358  
\[21.12.2\] Wernicke’s Aphasia 359  
\[21.12.3\] Conductive Aphasia 359  
\[21.12.4\] Global Aphasia 359  
21.13 Alexia 360  
21.14 Apraxia 360  
21.15 Gerstmann’s Syndrome 360  
21.16 Agnosia 360  
21.17 Dyslexia 360  
Further Reading 361

## Chapter 22  Blood Supply to the Central Nervous System  365

22.1 Cerebral Circulation 365  
22.2 Aortic Arch, Brachiocephalic Trunk, and Subclavian Vessels 366  
22.3 Vertebral–Basilar Arterial System 366  
\[22.3.1\] Branches of the Vertebral Arteries 367  
22.4 Blood Supply to the Spinal Cord 368  
\[22.4.1\] Extramedullary Vessels 368  
\[22.4.2\] Intramedullary Vessels 371  
\[22.4.3\] Spinal Veins 371  
22.5 Blood Supply to the Brain Stem and Cerebellum 372  
\[22.5.1\] Extrinsic or Superficial Branches 372  
\[22.5.2\] Branches of the Basilar Arteries 372  
\[22.5.3\] Intrinsic or Penetrating Branches 375  
\[22.5.4\] Classical Brain Stem Syndromes 377  
22.6 Common Carotid Artery 378  
\[22.6.1\] External Carotid Artery 378  
\[22.6.2\] Internal Carotid Artery: Cervical, Petrous, and Cavernous Parts 379  
22.7 Blood Supply to the Cerebral Hemispheres 379  
\[22.7.1\] Internal Carotid Artery: Cerebral Part 379  
\[22.7.2\] Branches of the Internal Carotid Artery 379  
\[22.7.3\] Posterior Cerebral Artery 383