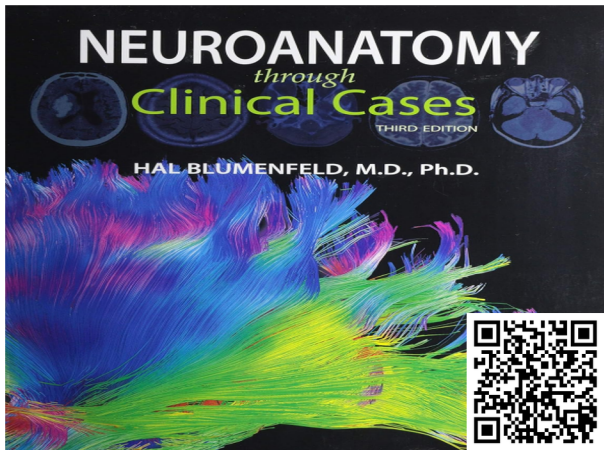


## Neuroanatomy through Clinical Cases 3rd Edition PDF

Visit the link below to download the full version of the ebook

**[DOWNLOAD NOW](#)**



Scan to Download  
or Type the Link

**[ebook.ac/neuroanatomy3e](http://ebook.ac/neuroanatomy3e)**

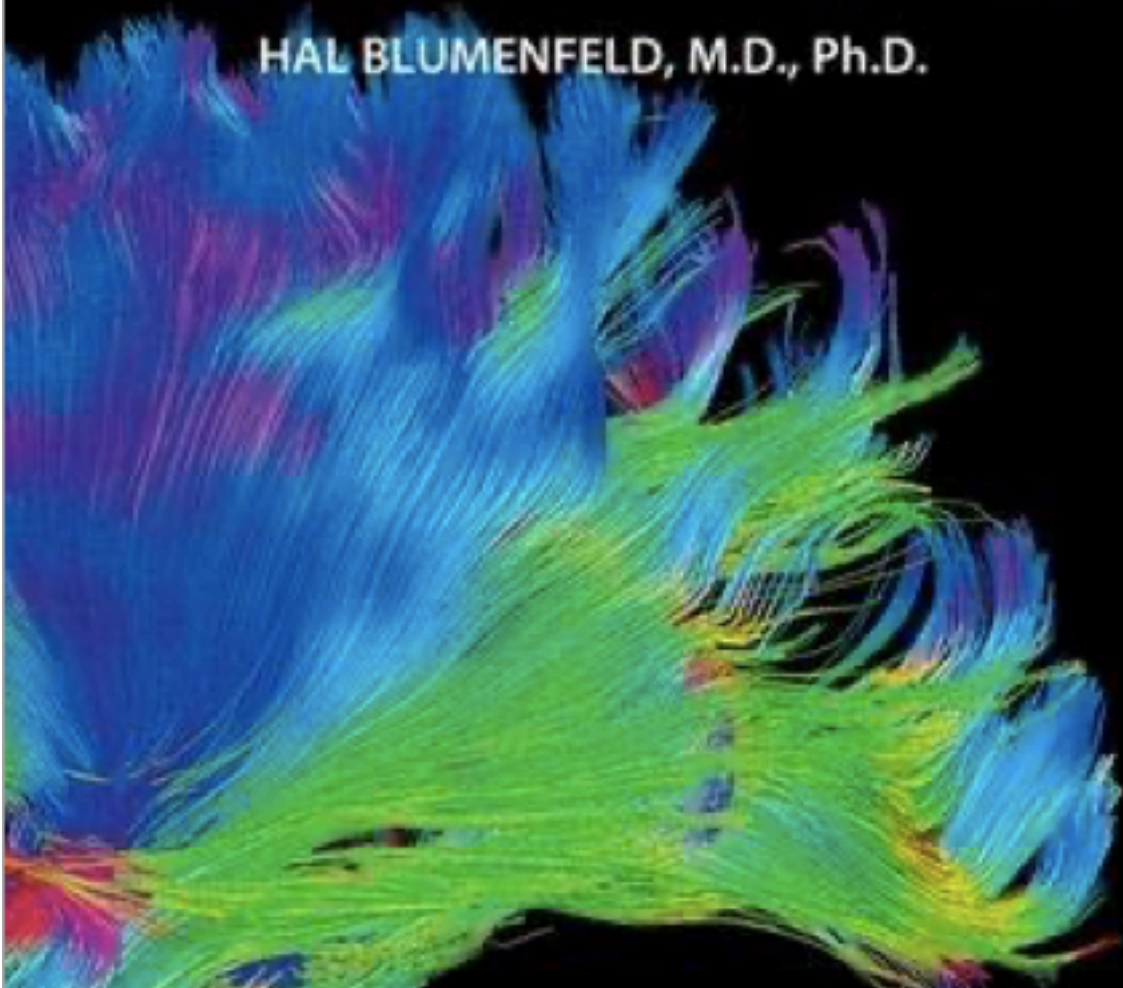
# NEUROANATOMY

*through*

## Clinical Cases

THIRD EDITION

HAL BLUMENFELD, M.D., Ph.D.



# Neuroanatomy through Clinical Cases

THIRD EDITION

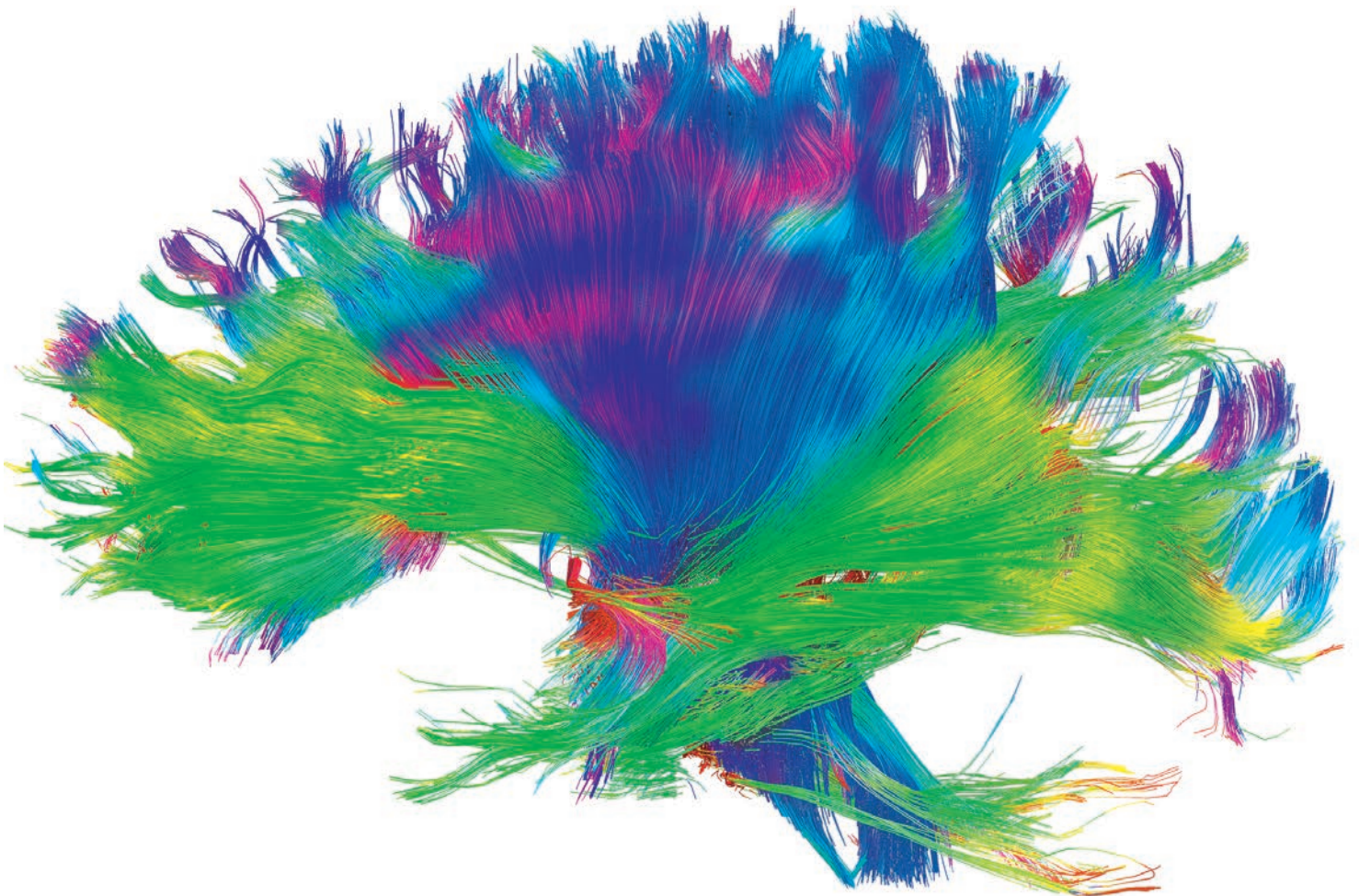


# NEUROANATOMY

*through*  
**Clinical Cases**

THIRD EDITION

**HAL BLUMENFELD, M.D., Ph.D.**  
*Yale University School of Medicine*



 SINAUER ASSOCIATES

NEW YORK OXFORD  
OXFORD UNIVERSITY PRESS

## Note

The author and the publisher have made every effort to provide clinical information in this book that is up-to-date and accurate at the time of publication. However, diagnostic and therapeutic methods evolve continuously based on new research and clinical experience. Because medical standards are constantly changing, and because of the possibility of human error, neither the author, nor the publisher, nor any other party who has been involved in the preparation or publication of this work warrants that the information contained herein is in every respect accurate or complete, and they disclaim all responsibility for any errors or omissions, or for clinical results obtained from use of the information contained in this work. Readers are strongly encouraged to consult other sources to confirm all clinical information when caring for patients, particularly in regard to treatments and medications, doses, and contraindications, which are subject to frequent changes and improvements, or when using new or infrequently used drugs or other treatments.

## The Cover

Human brain white matter tracts are revealed by MRI diffusion tractography. Fibers traveling in the anterior-posterior direction are shown in green, superior-inferior in blue, and medial-lateral in red. View is of the posterior left hemisphere seen from the left lateral surface. Modified with permission from Living Art Enterprises/Science Source.

Oxford University Press is a department of the University of Oxford. It furthers the University's objective of excellence in research, scholarship, and education by publishing worldwide. Oxford is a registered trade mark of Oxford University Press in the UK and certain other countries.

Published in the United States of America by Oxford University Press  
198 Madison Avenue, New York, NY 10016, United States of America

© 2022, 2010, 2002 Oxford University Press  
Sinuer Associates is an imprint of Oxford University Press.

For titles covered by Section 112 of the US Higher Education Opportunity Act, please visit [www.oup.com/us/he](http://www.oup.com/us/he) for the latest information about pricing and alternate formats.

All rights reserved. No part of this publication may be reproduced, stored in a retrieval system, or transmitted, in any form or by any means, without the prior permission in writing of Oxford University Press, or as expressly permitted by law, by license, or under terms agreed with the appropriate reproduction rights organization.

Inquiries concerning reproduction outside the scope of the above should be sent to the Rights Department, Oxford University Press, at the address above.

You must not circulate this work in any other form and you must impose this same condition on any acquirer.

Address editorial correspondence to:  
Sinuer Associates  
23 Plumtree Road  
Sunderland, MA 01375 USA

Address orders, sales, license, permissions,  
and translation inquiries to:  
Oxford University Press USA  
2001 Evans Road  
Cary, NC 27513 USA  
Orders: 1-800-445-9714

## Notice of Trademarks

Throughout this book trademark names have been used, and in some instances, depicted. In lieu of appending the trademark symbol to each occurrence, the authors and publisher state that these trademarks are used in an editorial fashion, to the benefit of the trademark owners, and with no intent to infringe upon the trademarks.

**ACCESSIBLE COLOR CONTENT** Every opportunity has been taken to ensure that the content herein is fully accessible to those who have difficulty perceiving color. Exceptions are cases where the colors provided are expressly required because of the purpose of the illustration.

## Library of Congress Cataloging-in-Publication Data

Names: Blumenfeld, Hal, author.

Title: Neuroanatomy through clinical cases / Hal Blumenfeld.

Description: Third edition. | New York, NY : Sinuer Associates/Oxford University

Press, [2021] | Includes bibliographical references and index.

Identifiers: LCCN 2020004534 (print) | LCCN 2020004535 (ebook) | ISBN 9781605359625 (paperback) | ISBN 9781605359632 (ebook)

Subjects: MESH: Nervous System Diseases--diagnosis | Nervous System--anatomy & histology | Nervous System--pathology | Case Reports

Classification: LCC RC346 (print) | LCC RC346 (ebook) | NLM WL 141 | DDC 616.8--dc23

LC record available at <https://lcn.loc.gov/2020004534>

LC ebook record available at <https://lcn.loc.gov/2020004535>

9 8 7 6 5 4 3 2 1

Printed in the United States of America

To Michelle

... 2018

# *Brief Contents*

- 1 ■ Introduction to Clinical Case Presentations 3
  - 2 ■ Neuroanatomy Overview and Basic Definitions 13
  - 3 ■ The Neurologic Exam as a Lesson in Neuroanatomy 49
  - 4 ■ Introduction to Clinical Neuroradiology 85
  - 5 ■ Brain and Environs: Cranium, Ventricles, and Meninges 125
  - 6 ■ Corticospinal Tract and Other Motor Pathways 221
  - 7 ■ Somatosensory Pathways 273
  - 8 ■ Spinal Nerve Roots 317
  - 9 ■ Major Plexuses and Peripheral Nerves 355
  - 10 ■ Cerebral Hemispheres and Vascular Supply 389
  - 11 ■ Visual System 459
  - 12 ■ Brainstem I: Surface Anatomy and Cranial Nerves 495
  - 13 ■ Brainstem II: Eye Movements and Pupillary Control 567
  - 14 ■ Brainstem III: Internal Structures and Vascular Supply 615
  - 15 ■ Cerebellum 699
  - 16 ■ Basal Ganglia 741
  - 17 ■ Pituitary and Hypothalamus 795
  - 18 ■ Limbic System: Homeostasis, Olfaction, Memory, and Emotion 823
  - 19 ■ Higher-Order Cerebral Function 887
- Epilogue: A Simple Working Model of the Mind 987

# Contents

PREFACE xvi

HOW TO USE THIS BOOK xx

## Chapter 1 *Introduction to Clinical Case Presentations* 3

**Introduction** 4

**The General History and Physical Exam** 4

Chief Complaint (CC) 5

History of the Present Illness (HPI) 5

Past Medical History (PMH) 6

Review of Systems (ROS) 6

Family History (FHx) 6

Social and Environmental History (SocHx/EnvHx) 6

Medications and Allergies 6

Physical Exam 6

Laboratory Data 7

Assessment and Plan 7

**Neurologic Differential Diagnosis** 7

**Relationship between the General Physical Exam  
and the Neurologic Exam** 8

**Conclusions** 10

**References** 10

## Chapter 2 *Neuroanatomy Overview and Basic Definitions* 13

**Basic Macroscopic Organization of  
the Nervous System** 14

Main Parts of the Nervous System 14

Orientation and Planes of Section 16

**Basic Cellular and Neurochemical Organization of  
the Nervous System** 17

**CNS Gray Matter and White Matter; PNS Ganglia  
and Nerves** 21

**Spinal Cord and Peripheral Nervous System** 22

**Cerebral Cortex: Basic Organization and Primary  
Sensory and Motor Areas** 24

Lobes of the Cerebral Hemispheres 24

Surface Anatomy of the Cerebral Hemispheres in Detail 25

Primary Sensory and Motor Areas 28

Cell Layers and Regional Classification of  
the Cerebral Cortex 29

**Motor Systems** 32

Main Motor Pathways 32

Cerebellum and Basal Ganglia 34

**Somatosensory Systems** 34

Main Somatosensory Pathways 34

Thalamus 35

**Stretch Reflex** 37

**Brainstem and Cranial Nerves** 38

**Limbic System** 41

**Association Cortex** 41

**Blood Supply to the Brain and Spinal Cord** 44

**Conclusions** 46

**References** 46

## Chapter 3 *The Neurologic Exam as a Lesson in Neuroanatomy* 49

Overview of the Neurologic Exam 50

neuroexam.com 52

The Neurologic Exam: Examination Technique and What Is Being Tested 52

1. Mental Status 52
2. Cranial Nerves 58
3. Motor Exam 63
4. Reflexes 66
5. Coordination and Gait 68
6. Sensory Exam 71

The Neurologic Exam as a Flexible Tool 72

Exam Limitations and Strategies 73

Coma Exam 73

General Physical Exam 74

1. Mental Status 75
2. Cranial Nerves 76
3. Sensory Exam and 4. Motor Exam 77
5. Reflexes 77
6. Coordination and Gait 79

Brain Death 79

Conversion Disorder, Malingering, and Related Disorders 79

The Screening Neurologic Exam 81

Conclusions 81

References 46

## Chapter 4 *Introduction to Clinical Neuroradiology* 85

Introduction 86

Imaging Planes 86

Computed Tomography 86

CT versus MRI 89

Magnetic Resonance Imaging 90

Neuroangiography 98

Functional Neuroimaging 100

Conclusions 101

NEURORADIOLOGICAL ATLAS 102

References 123

## Chapter 5 *Brain and Environs: Cranium, Ventricles, and Meninges* 125

**ANATOMICAL AND CLINICAL REVIEW** 126

Cranial Vault and Meninges 126

Ventricles and Cerebrospinal Fluid 132

Blood–Brain Barrier 137

- KCC 5.1** Headache 139
- KCC 5.2** Intracranial Mass Lesions 141
- KCC 5.3** Elevated Intracranial Pressure 142
- KCC 5.4** Brain Herniation Syndromes 145
- KCC 5.5** Head Trauma 147
- KCC 5.6** Intracranial Hemorrhage 148
- KCC 5.7** Hydrocephalus 156
- KCC 5.8** Brain Tumors 158
- KCC 5.9** Infectious Disorders of the Nervous System 160
- KCC 5.10** Lumbar Puncture 167
- KCC 5.11** Craniotomy 169

**CLINICAL CASES** 170

- 5.1** An Elderly Man with Headaches and Unsteady Gait 170
- 5.2** Altered Mental Status Following Head Injury 173

**5.3** Delayed Unresponsiveness after Head Injury 180

**5.4** Headache and Progressive Left-Sided Weakness 183

**5.5** Sudden Coma and Bilateral Posturing during Intravenous Anticoagulation 187

**5.6** Severe Head Injury 190

**5.7** A Child with Headaches, Nausea, and Diplopia 195

**5.8** Headaches and Progressive Visual Loss 203

**5.9** An Elderly Man with Progressive Gait Difficulty, Cognitive Impairment, and Incontinence 208

**5.10** A Young Man with Headache, Fever, Confusion, and Stiff Neck 212

**Additional Cases** 213

**BRIEF ANATOMICAL STUDY GUIDE** 214

**A Scuba Expedition through the Brain** 215

**References** 217

## Chapter 6 Corticospinal Tract and Other Motor Pathways 221

### ANATOMICAL AND CLINICAL REVIEW 222

Motor Cortex, Sensory Cortex, and Somatotopic Organization 222

Basic Anatomy of the Spinal Cord 224

Spinal Cord Blood Supply 227

General Organization of the Motor Systems 228

Lateral Corticospinal Tract 230

Autonomic Nervous System 236

**KCC 6.1** Upper Motor Neuron versus Lower Motor Neuron Lesions 239

**KCC 6.2** Terms Used to Describe Weakness 240

**KCC 6.3** Weakness Patterns and Localization 240

**KCC 6.4** Detecting Subtle Hemiparesis at the Bedside 248

**KCC 6.5** Unsteady Gait 249

**KCC 6.6** Multiple Sclerosis 250

**KCC 6.7** Motor Neuron Disease 252

### CLINICAL CASES 253

**6.1** Sudden Onset of Right Hand Weakness 253

**6.2** Sudden Onset of Left Foot Weakness 254

**6.3** Sudden Onset of Right Face Weakness 255

**6.4** Pure Motor Hemiparesis I 261

**6.5** Pure Motor Hemiparesis II 262

**6.6** Progressive Weakness, Muscle Twitching, and Cramps 265

### Additional Cases 266

### BRIEF ANATOMICAL STUDY GUIDE 267

### References 268

## Chapter 7 Somatosensory Pathways 273

### ANATOMICAL AND CLINICAL REVIEW 274

Main Somatosensory Pathways 274

Posterior Column–Medial Lemniscal Pathway 277

Spinothalamic Tract and Other Anterolateral Pathways 278

Somatosensory Cortex 280

Central Modulation of Pain 280

The Thalamus 280

**KCC 7.1** Paresthesias 286

**KCC 7.2** Spinal Cord Lesions 286

**KCC 7.3** Sensory Loss: Patterns and Localization 288

**KCC 7.4** Spinal Cord Syndromes 290

**KCC 7.5** Anatomy of Bowel, Bladder, and Sexual Function 293

### CLINICAL CASES 296

**7.1** Sudden Onset of Right Arm Numbness 296

**7.2** Sudden Onset of Right Face, Arm, and Leg Numbness 300

**7.3** A Fall Causing Paraplegia and a Sensory Level 301

**7.4** Left Leg Weakness and Right Leg Numbness 303

**7.5** Sensory Loss over Both Shoulders 305

**7.6** Body Tingling and Unsteady Gait 307

**7.7** Hand Weakness, Pinprick Sensory Level, and Urinary Retention 309

### Additional Cases 311

### BRIEF ANATOMICAL STUDY GUIDE 311

### References 313

## Chapter 8 Spinal Nerve Roots 317

### ANATOMICAL AND CLINICAL REVIEW 318

Segmental Organization of the Nervous System 318

Nerve Roots in Relation to Vertebral Bones, Discs, and Ligaments 319

Dermatomes and Myotomes 321

**KCC 8.1** Disorders of Nerve, Neuromuscular Junction, and Muscle 325

**KCC 8.2** Back Pain 328

**KCC 8.3** Radiculopathy 330

**Simplification: Three Nerve Roots to Remember in the Arm 332**

**Simplification: Three Nerve Roots to Remember in the Leg 332**

**KCC 8.4** Cauda Equina Syndrome 332

**KCC 8.5** Common Surgical Approaches to the Spine 333

### CLINICAL CASES 334

**8.1** Unilateral Neck Pain and Tingling Numbness in the Thumb and Index Finger 334

**8.2** Unilateral Occipital and Neck Pain 335

## x Contents

- 8.3 Unilateral Shoulder Pain and Weakness 335
- 8.4 Blisters, Pain, and Weakness in the Left Arm 338
- 8.5 Unilateral Shoulder Pain and Numbness in the Index and Middle Fingers 339
- 8.6 Unilateral Neck Pain, Hand Weakness, and Numbness in the Ring and Little Fingers 340
- 8.7 Pain and Numbness in the Medial Arm 341
- 8.8 Low Back Pain Radiating to the Sole of the Foot and the Small Toe 341

- 8.9 Unilateral Thigh Weakness with Pain Radiating to the Anterior Shin 343
- 8.10 Low Back Pain Radiating to the Big Toe 346
- 8.11 Saddle Anesthesia with Loss of Sphincteric and Erectile Function 347

### Additional Cases 349

### BRIEF ANATOMICAL STUDY GUIDE 349

### References 352

## Chapter 9 Major Plexuses and Peripheral Nerves 355

### ANATOMICAL AND CLINICAL REVIEW 356

#### Brachial Plexus and Lumbosacral Plexus 356

#### Simplification: Five Nerves to Remember in the Arm 358

#### Simplification: Three Nerves Acting on the Thumb 360

#### Intrinsic and Extrinsic Hand Muscles 360

#### Simplification: Five Nerves to Remember in the Leg 361

- KCC 9.1 Common Plexus and Nerve Syndromes 362
- KCC 9.2 Electromyography (EMG) and Nerve Conduction Studies 365

### CLINICAL CASES 367

- 9.1 Complete Paralysis and Loss of Sensation in One Arm 367
- 9.2 A Newborn with Weakness in One Arm 369
- 9.3 A Blow to the Medial Arm Causing Hand Weakness and Numbness 370

- 9.4 Nocturnal Pain and Tingling in the Thumb, Pointer, and Middle Finger 371

- 9.5 Hand and Wrist Weakness after a Fall 372

- 9.6 Numbness and Tingling in the Pinky and Ring Finger 373

- 9.7 Shoulder Weakness and Numbness after Strangulation 374

- 9.8 Unilateral Thigh Pain, Weakness, and Numbness in a Diabetic 375

- 9.9 Tingling and Paralysis of the Foot after a Fall 375

- 9.10 A Leg Injury Resulting in Foot Drop 377

- 9.11 Lateral Thigh Pain and Numbness after Pregnancy 379

- 9.12 Dysarthria, Ptosis, and Decreased Exercise Tolerance 379

- 9.13 Generalized Weakness and Areflexia 381

- 9.14 Mysterious Weakness after Dinner 383

### Additional Cases 384

### BRIEF ANATOMICAL STUDY GUIDE 384

### References 385

## Chapter 10 Cerebral Hemispheres and Vascular Supply 389

### ANATOMICAL AND CLINICAL REVIEW 390

#### Review of Main Functional Areas of Cerebral Cortex 390

#### Circle of Willis: Anterior and Posterior Circulations 391

#### Anatomy and Vascular Territories of the Three Main Cerebral Arteries 393

- KCC 10.1 Clinical Syndromes of the Three Cerebral Arteries 398
- KCC 10.2 Watershed Infarcts 400
- KCC 10.3 Transient Ischemic Attack and Other Transient Neurologic Episodes 401
- KCC 10.4 Ischemic Stroke: Mechanisms and Treatment 402
- KCC 10.5 Carotid Stenosis 408
- KCC 10.6 Dissection of the Carotid or Vertebral Arteries 409

#### Venous Drainage of the Cerebral Hemispheres 409

- KCC 10.7 Sagittal Sinus Thrombosis 418

### CLINICAL CASES 411

- 10.1 Sudden-Onset Worst Headache of Life 411

- 10.2 Left Leg Weakness and Left Alien Hand Syndrome 413

- 10.3 Decreased Vision on One Side 414

- 10.4 Transient Episodes of Left Eye Blurriness or Right Hand Weakness 423

- 10.5 Nonfluent Aphasia with Right Face and Arm Weakness 425

- 10.6 "Talking Ragtime" 427

- 10.7 Dysarthria and Hemiparesis 430

- 10.8 Global Aphasia, Right Hemiplegia, and Hemianopia 432

- 10.9 Left Face and Arm Weakness 435
- 10.10 Left Hemineglect 436
- 10.11 Left Hemineglect, Hemiplegia, and Hemianopia 438
- 10.12 Unilateral Proximal Arm and Leg Weakness 444
- 10.13 Right Frontal Headache and Left Arm Numbness in a Woman with Gastric Carcinoma 449

## Chapter 11 *Visual System* 459

### ANATOMICAL AND CLINICAL REVIEW 460

Eyes and Retina 460

Optic Nerves, Optic Chiasm, and  
Optic Tracts 463

Lateral Geniculate Nucleus and Extrageniculate  
Pathways 464

Optic Radiations to Primary Visual Cortex 465

Visual Processing in the Neocortex 466

**KCC 11.1** Assessment of Visual Disturbances 470

**KCC 11.2** Localization of Visual Field Defects 472

**KCC 11.3** Blood Supply and Ischemia in  
the Visual Pathways 476

**KCC 11.4** Optic Neuritis 477

Additional Cases 453

**BRIEF ANATOMICAL STUDY GUIDE** 453

References 454

### CLINICAL CASES 478

11.1 A Dark Spot Seen with One Eye 478

11.2 Vision Loss in One Eye 479

11.3 Menstrual Irregularity and Bitemporal Hemianopia 481

11.4 Hemianopia after Treatment for a Temporal  
Lobe Tumor 483

11.5 Visual Changes Caused by Migraine Headaches? 485

11.6 Sudden Loss of Left Vision 486

11.7 Visual Field Match-Up 489

Additional Cases 490

**BRIEF ANATOMICAL STUDY GUIDE** 492

References 493

## Chapter 12 *Brainstem I: Surface Anatomy and Cranial Nerves* 495

### ANATOMICAL AND CLINICAL REVIEW 496

Surface Features of the Brainstem 497

Skull Foramina and Cranial Nerve  
Exit Points 500

Sensory and Motor Organization of  
the Cranial Nerves 502

Functions and Course of the Cranial Nerves 505

CN I: Olfactory Nerve 507

**KCC 12.1** Anosmia (CN I) 508

CN II: Optic Nerve 508

CN III, IV, and VI: Oculomotor, Trochlear, and  
Abducens Nerves 508

CN V: Trigeminal Nerve 510

**KCC 12.2** Trigeminal Nerve Disorders (CN V) 514

CN VII: Facial Nerve 515

**KCC 12.3** Facial Nerve Lesions (CN VII) 518

**KCC 12.4** Corneal Reflex and Jaw Jerk Reflex (CN V, VII) 520

CN VIII: Vestibulocochlear Nerve 520

**KCC 12.5** Hearing Loss (CN VIII) 527

**KCC 12.6** Dizziness and Vertigo (CN VIII) 529

CN IX: Glossopharyngeal Nerve 532

CN X: Vagus Nerve 534

CN XI: Spinal Accessory Nerve 536

CN XII: Hypoglossal Nerve 537

**KCC 12.7** Disorders of CN IX, X, XI, and XII 537

**KCC 12.8** Hoarseness, Dysarthria, Dysphagia, and  
Pseudobulbar Affect 538

Review: Cranial Nerve Combinations 539

### CLINICAL CASES 541

12.1 Anosmia and Visual Impairment 541

12.2 Cheek Numbness and a Bulging Eye 543

12.3 Jaw Numbness and Episodes of Loss of  
Consciousness 544

12.4 Isolated Facial Weakness 545

12.5 Hearing Loss and Dizziness 550

12.6 Hoarse Voice Following Cervical Disc Surgery 551

12.7 Hoarseness, with Unilateral Wasting of the Neck and  
Tongue Muscles 555

12.8 Uncontrollable Laughter, Dysarthria, Dysphagia, and  
Left-Sided Weakness 557

Additional Cases 561

**BRIEF ANATOMICAL STUDY GUIDE** 561

References 563

## Chapter 13 *Brainstem II: Eye Movements and Pupillary Control* 567

### ANATOMICAL AND CLINICAL REVIEW 568

#### Extraocular Muscles, Nerves, and Nuclei 568

- KCC 13.1 Diplopia 573
- KCC 13.2 Oculomotor Palsy (CN III) 574
- KCC 13.3 Trochlear Palsy (CN IV) 576
- KCC 13.4 Abducens Palsy (CN VI) 577

#### The Pupils and Other Ocular Autonomic Pathways 578

- KCC 13.5 Pupillary Abnormalities 581
- KCC 13.6 Ptosis 584

#### Cavernous Sinus and Orbital Apex 585

- KCC 13.7 Cavernous Sinus Syndrome (CN III, IV, VI, V<sub>1</sub>) and Orbital Apex Syndrome (CN II, III, IV, VI, V<sub>1</sub>) 586

#### Supranuclear Control of Eye Movements 586

- KCC 13.8 Brainstem Lesions Affecting Horizontal Gaze 588
- KCC 13.9 Parinaud's Syndrome 590
- KCC 13.10 Right-Way Eyes and Wrong-Way Eyes 591

### CLINICAL CASES 593

- 13.1 Double Vision and Unilateral Eye Pain 593
- 13.2 A Diabetic with Horizontal Diplopia 595
- 13.3 Vertical Diplopia 596
- 13.4 Left Eye Pain and Horizontal Diplopia 597
- 13.5 Unilateral Headache, Ophthalmoplegia, and Forehead Numbness 598
- 13.6 Ptosis, Miosis, and Anhidrosis 600
- 13.7 Wrong-Way Eyes 604
- 13.8 Horizontal Diplopia in a Patient with Multiple Sclerosis 605
- 13.9 Headaches and Impaired Upgaze 606

### Additional Cases 607

### BRIEF ANATOMICAL STUDY GUIDE 609

### References 612

## Chapter 14 *Brainstem III: Internal Structures and Vascular Supply* 615

### ANATOMICAL AND CLINICAL REVIEW 616

#### Main Components of the Brainstem 616

#### Brainstem Sections 617

#### Cranial Nerve Nuclei and Related Structures 624

#### Long Tracts 626

- KCC 14.1 Locked-In Syndrome 627

#### Cerebellar Circuitry 627

#### Reticular Formation and Related Structures 628

#### The Consciousness System 629

#### Widespread Projection Systems of Brainstem and Forebrain: Consciousness, Attention, and Other Functions 632

#### Anatomy of the Sleep–Wake Cycle 638

- KCC 14.2 Coma and Related Disorders 642

#### Other Brainstem Motor, Reflex, and Autonomic Systems 648

#### Brainstem Vascular Supply 650

- KCC 14.3 Vertebrobasilar Vascular Disease 656

### CLINICAL CASES 663

- 14.1 Face and Contralateral Body Numbness, Hoarseness, Horner's Syndrome, and Ataxia 663
- 14.2 Hemiparesis Sparing the Face 665
- 14.3 Dysarthria and Hemiparesis 670
- 14.4 Unilateral Face Numbness, Hearing Loss, and Ataxia 671
- 14.5 Locked-In 675
- 14.6 Wrong-Way Eyes, Limited Upgaze, Decreased Responsiveness, and Hemiparesis with an Amazing Recovery 677
- 14.7 Diplopia and Unilateral Ataxia 684
- 14.8 Intermittent Memory Loss, Diplopia, Sparkling Lights, and Somnolence 685
- 14.9 Intractable Hiccups 689

### Additional Cases 690

### BRIEF ANATOMICAL STUDY GUIDE 694

### References 695

## Chapter 15 Cerebellum 699

### ANATOMICAL AND CLINICAL REVIEW 700

Cerebellar Lobes, Peduncles, and  
Deep Nuclei 700

Microscopic Circuitry of the Cerebellum 705

Cerebellar Output Pathways 707

Cerebellar Input Pathways 710

Vascular Supply to the Cerebellum 713

**KCC 15.1** Cerebellar Artery Infarcts and Cerebellar  
Hemorrhage 715

**KCC 15.2** Clinical Findings and Localization of  
Cerebellar Lesions 716

**KCC 15.3** Differential Diagnosis of Ataxia 721

## Chapter 16 Basal Ganglia 741

### ANATOMICAL AND CLINICAL REVIEW 742

Basic Three-Dimensional Anatomy of the Basal  
Ganglia 742

Input, Output, and Intrinsic Connections of  
the Basal Ganglia 750

Parallel Basal Ganglia Pathways for General  
Movement, Eye Movement, Cognition,  
and Emotion 754

Ansa Lenticularis, Lenticular Fasciculus, and  
the Fields of Forel 756

**KCC 16.1** Movement Disorders 757

**KCC 16.2** Parkinson's Disease and Related Disorders 765

**KCC 16.3** Huntington's Disease 769

**KCC 16.4** Stereotactic Neurosurgery and Deep Brain  
Stimulation 771

## Chapter 17 Pituitary and Hypothalamus 795

### ANATOMICAL AND CLINICAL REVIEW 796

Overall Anatomy of the Pituitary and  
Hypothalamus 796

Important Hypothalamic Nuclei and  
Pathways 798

Endocrine Functions of the Pituitary  
and Hypothalamus 801

**KCC 17.1** Pituitary Adenoma and Related Disorders 804

**KCC 17.2** Diabetes Insipidus and SIADH 807

**KCC 17.3** Panhypopituitarism 808

### CLINICAL CASES 722

**15.1** Sudden Onset of Unilateral Ataxia 722

**15.2** Walking Like a Drunkard 723

**15.3** A Boy with Headaches, Nausea, Slurred Speech,  
and Ataxia 727

**15.4** Nausea, Progressive Unilateral Ataxia, and  
Right Face Numbness 729

**15.5** A Family with Slowly Progressive Ataxia  
and Dementia 733

### Additional Cases 734

### BRIEF ANATOMICAL STUDY GUIDE 735

### References 738

### CLINICAL CASES 773

**16.1** Unilateral Flapping and Flinging 773

**16.2** Irregular Jerking Movements and Marital Problems 774

**16.3** Asymmetrical Resting Tremor, Rigidity, Bradykinesia,  
and Gait Difficulties 777

**16.4** Bilateral Bradykinesia, Rigidity, and Gait Instability  
with No Tremor 781

**16.5** Childhood Dystonia 784

### Additional Cases 789

### BRIEF ANATOMICAL STUDY GUIDE 789

### References 790

### CLINICAL CASES 809

**17.1** Moon Facies, Acne, Amenorrhea, and  
Hypertension 809

**17.2** Impotence, Anorexia, Polyuria, Blurred Vision,  
Headaches, and Hearing Loss 813

**17.3** A Child with Giggling Episodes and  
Aggressive Behavior 815

### Additional Cases 816

### BRIEF ANATOMICAL STUDY GUIDE 819

### References 820

## Chapter 18 *Limbic System: Homeostasis, Olfaction, Memory, and Emotion* 823

### **ANATOMICAL AND CLINICAL REVIEW** 824

**Overview of Limbic Structures** 825

**Olfactory System** 831

**Hippocampal Formation and Other Memory-Related Structures** 833

**KCC 18.1** Memory Function and Memory Disorders 842

**The Amygdala: Emotions, Drives, and Other Functions** 849

**Other Limbic Pathways** 852

**KCC 18.2** Seizures and Epilepsy 852

**KCC 18.3** Anatomical and Neuropharmacological Basis of Psychiatric Disorders 862

### **CLINICAL CASES** 865

**18.1** Sudden Memory Loss after a Mild Head Injury 865

**18.2** Progressive Severe Memory Loss, with Mild Confabulation 866

**18.3** Memory Loss, Double Vision, and Incoordination 869

**18.4** Episodes of Panic, Olfactory Hallucinations, and Loss of Awareness 871

**18.5** Episodes of Staring, Lip Smacking, and Unilateral Semipurposeful Movements 875

**Additional Cases** 877

### **BRIEF ANATOMICAL STUDY GUIDE** 881

**References** 883

## Chapter 19 *Higher-Order Cerebral Function* 887

### **ANATOMICAL AND CLINICAL REVIEW** 888

**KCC 19.1** The Mental Status Exam 888

**Unimodal and Heteromodal Association Cortex** 889

**Principles of Cerebral Localization and Lateralization** 891

**The Dominant Hemisphere: Language Processing and Related Functions** 893

**KCC 19.2** Differential Diagnosis of Language Disorders 896

**KCC 19.3** Bedside Language Exam 897

**KCC 19.4** Broca's Aphasia 897

**KCC 19.5** Wernicke's Aphasia 899

**KCC 19.6** Simplified Aphasia Classification Scheme 900

**KCC 19.7** Other Syndromes Related to Aphasia 902

**KCC 19.8** Disconnection Syndromes 905

**The Nondominant Hemisphere: Spatial Processing and Lateralized Attention** 906

**KCC 19.9** Hemineglect Syndrome 908

**KCC 19.10** Other Clinical Features of Nondominant Hemisphere Lesions 913

**The Frontal Lobes: Anatomy and Functions of an Enigmatic Brain Region** 914

**KCC 19.11** Frontal Lobe Disorders 916

**Visual Association Cortex: Higher-Order Visual Processing** 921

**KCC 19.12** Disorders of Higher-Order Visual Processing 922

**KCC 19.13** Auditory Hallucinations 925

**The Consciousness System Revisited: Anatomy of Attention** 926

**KCC 19.14** Attentional Disorders 930

**KCC 19.15** Delirium and Other Acute Mental Status Disorders 932

**KCC 19.16** Dementia and Other Chronic Mental Status Disorders 934

**Brain Mechanisms of Conscious Awareness: Detect, Pulse, Switch, and Wave Model** 942

### **CLINICAL CASES** 948

**19.1** Acute Severe Aphasia, with Improvement 948

**19.2** Nonsensical Speech 950

**19.3** Aphasia with Preserved Repetition 951

**19.4** Impaired Repetition 953

**19.5** Inability to Read, with Preserved Writing Skills 956

**19.6** Left Hemineglect 961

**19.7** Abulia 963

**19.8** Blindness without Awareness of Deficit 967

**19.9** Sudden Inability to Recognize Faces 971

**19.10** Musical Hallucinations 972

**19.11** Progressive Dementia, Beginning with Memory Problems 973

**Additional Cases** 975

### **BRIEF ANATOMICAL STUDY GUIDE** 977

**References** 980

Epilogue: A Simple Working Model of the Mind 987

Case Index 991

Subject Index 997

# Preface

Neuroanatomy is a living, dynamic field that can bring both intellectual delight and aesthetic pleasure to students at all levels. However, by nature, it is also an exceedingly detailed subject, and herein lies the tragic pitfall of all too many neuroanatomy courses. Crushing amounts of memorization are often required of students of neuroanatomy, leaving them little time to step back and gain an appreciation of the structural and functional beauty of the nervous system and its relevance to clinical practice.

This book has a different point of view: instead of making the mastery of anatomical details the main goal and then searching for applications of this knowledge, actual clinical cases are used as both a teaching instrument and a motivating force to encourage students to delve into further study of normal anatomy and function. Through this approach, structural details take on immediate relevance as they are being learned. In addition, each clinical case is an ideal way to integrate knowledge of disparate functional systems, since a single lesion may affect several different neural structures and pathways.

Over 100 clinical cases, accompanied by neuroradiological images, are presented in this text, and I am grateful to many neurologists, neurosurgeons, and neuroradiologists at the Columbia, Harvard, and Yale medical schools for helping me to amass enough material to present clinically relevant discussions of the entire nervous system. I have used this book's diagnostic method to teach neuroanatomy at these medical schools, and both students and faculty greeted the innovation enthusiastically. Through publication of *Neuroanatomy through Clinical Cases* I hope that students and faculty at many additional institutions will find this to be an enjoyable and effective way to learn neuroanatomy and its real-life applications.

## Acknowledgments for First Edition

First and foremost, I must thank my wife Michelle, and our children Eva and Jesse, for their enthusiasm and support throughout the writing and publication of this book.

This project has spanned a number of years, and stints at several academic centers, so there is a formidable list of people whom I must thank for their important contributions. This book was conceived while I was teaching neuroanatomy as an M.D., Ph.D. student at Columbia Medical School, where I was inspired by my teachers Eric Kandel, Jack Martin, and Steven Siegelbaum. They have remained invaluable sources of inspiration and advice ever since. I would also like to thank the following individuals who served as mentors, benefactors, or role models during my training as a neurologist and neuroscientist: Raymond D. Adams, Bernard Cohen, C. Miller Fisher, Jack Haimovic, Walter Koroshetz, Terry Krulwich, Elan Louis, Stephan Mayer, David McCormick, Thomas McMahon, Timothy Pedley, Pasko Rakic, Susan Spencer, Dennis Spencer, Stephen Waxman, Anne Young, and George Zubal. I would also like to offer special thanks to those who were my closest colleagues and friends during my neurology residency: Jang-Ho Cha, Mitchell

Elkind, Martha Herbert, David Jacoby, Michael Lin, Guy Rordorff, Diana Rosas, and Gerald So.

The focus and main strength of this book is its clinical cases. Therefore, I am very grateful to the many colleagues who suggested the clinical cases used in this book: Robert Ackerman, Claudia Baldassano, Tracy Batchelor, Flint Beal, Carsten Bonneman, Lawrence Borges, Robert Brown, Jeffrey Bruce, Brad Buchbinder, Ferdinando Buonanno, William Butler, Steve Cannon, David Caplan, Robert Carter, Verne Caviness, Jang-Ho Cha, Paul Chapman, Chinfei Chen, Keith Chiappa, In Sup Choi, Andrew Cole, Douglas Cole, G. Rees Cosgrove, Steven Cramer, Didier Cros, Merit Cudkowicz, Kenneth Davis, Rajiv Desai, Elizabeth Dooling, Brad Duckrow, Mitchell Elkind, Emad Eskandar, Stephen Fink, Seth Finkelstein, Alice Flaherty, Robert Friedlander, David Frim, Zoher Ghogawala, Michael Goldrich, Jonathan Goldstein, R. Gilberto Gonzalez, Kimberly Goslin, Steven Greenberg, John Growdon, Andrea Halliday, E. Tessa Hedley-Whyte, Martha Herbert, Daniel Hoch, Fred Hochberg, J. Maurice Hourihane, Brad Hyman, Michael Irizarry, David Jacoby, William Johnson, Raymond Kelleher, Philip Kistler, Walter Koroshetz, Sandra Kostyk, Kalpathy Krishnamoorthy, James Lehrich, Simmons Lessell, Michael Lev, Susan Levy, Michael Lin, Elan Louis, David Louis, Jean Lud-Cadet, David Margolin, Richard Mattson, Stephan Mayer, James Miller, Shawn Murphy, Brad Navia, Steven Novella, Edward Novotny, Christopher Ogilvy, Robert Ojemann, Michael Panzara, Dante Pappano, Stephen Parker, Marie Pasinski, John Penney, Bruce Price, Peter Riskind, Guy Rordorff, Diana Rosas, Tally Sagie, Pamela Schaefer, Jeremy Schmahmann, Lee Schwamm, Michael Schwarzschild, Saad Shafqat, Barbara Shapiro, Aneesh Singhal, Michael Sisti, Gerald So, Robert Solomon, Marcio Sotero, Dennis Spencer, Susan Spencer, John Stakes, Marion Stein, Divya Subramanian-Khurana, Brooke Swearingen, Max Takeoka, Thomas Tatemichi, Fran Testa, James Thompson, Mark Tramo, Jean Paul Vonsattel, Shirley Wray, Anne Young, and Nicholas Zervas.

I am deeply indebted to the many individuals who provided critical reviews of one or more chapters, greatly enhancing the accuracy and clarity of the material in this book: Raymond D. Adams, Joshua Auerbach, William W. Blessing, Laura Blumenfeld, William Boonn, Lawrence Borges, Michelle Brody, Richard Bronen, Joshua Brumberg, Thomas N. Byrne, Mark Cabelin, Jang-Ho Cha, Jaehyuk Choi, Charles Conrad, Rees Cosgrove, Merit Cudkowicz, Mitchell Elkind, C. M. Fisher, David Frim, Darren R. Gitelman, Jonathan Goldstein, Gil Gonzalez, Charles Greer, Stephan Heckers, Tamas Horvath, Gregory Huth, Michael Irizarry, Joshua P. Klein, Igor Koralnack, John Krakauer, Matthew Kroh, Robert H. LaMotte, John Langfitt, Steven B. Leder, Elliot Lerner, Grant Liu, Andres Martin, John H. Martin, Ian McDonald, Lyle Mitzner, Hrachya Nersesyan, Andrew Norden, Robert Ojemann, Stephen Parker, Huned Patwa, Howard Pomeranz, Bruce Price, Anna Roe, David Ross, Jeremy Schmahmann, Mark Schwartz, Ted Schwartz, Michael Schwarzschild, Barbara Shapiro, Scott Small, Arien Smith, Adam Sorscher, Susan Spencer, Stephen M. Strittmatter, Larry Squire, Mircea Steriade, Ethan Taub, Timothy Vollmer, and Steven U. Walkley. I express my gratitude for their helpful suggestions, but accept full responsibility for any errors in this text.

Marty Wonsiewicz, John Dolan, Greg Huth, John Butler, and Amanda Suver were helpful in the early stages of editorial development of this book. Michael Schlosser and Tasha Tanhehco helped gather the references, and Jason Freeman and Susan Vanderhill helped obtain copyright permissions. Wendy Beck and BlackSheep Marketing designed and implemented the neuroexam.com website. The video segments for [neuroexam.com](http://neuroexam.com) and *The NeuroExam Video* were filmed by Douglas Forbush and Patrick Leone at Yale, and edited by Evan Jones of RBY Video. Milena Pavlova provided helpful suggestions, and played the role of the patient.

Finally, I thank the entire staff at Sinauer Associates for their tremendously helpful collaboration in all stages of producing this book. I have enjoyed working with, and am especially grateful to, Andrew D. Sinauer, Peter Farley, Kerry Falvey, Christopher Small, and Jefferson Johnson, but I extend my deep appreciation to all other members of the Sinauer staff as well. It is a pleasure to work with people who truly care about creating a fine book.

## **Additional Acknowledgments for Second Edition**

My family again comes first in my acknowledgments, as they stood closest by me through the long process of revising and updating this book. I thank Michelle for her advice and support, and our children Eva, Jesse, and Lev for their enthusiasm and for always bringing a smile to my face. Also, none of this would have been possible without my parents who continue to be a source of inspiration. My sister, “the real writer in the family,” and many other family members and close, lifelong friends complete the list of those most precious.

In addition to those listed in the Acknowledgments for the First Edition, I would also like to thank the following outstanding colleagues for their suggested cases or critical chapter reviews: Nazem Atassi, Joachim Baehring, Margaret Bia, William Blessing, Richard Bronen, Franklin Brown, Joshua Brumberg, Gordon Buchanan, Ketan Bulsara, Louis Caplan, Michael Carrithers, Jang-Ho Cha, Michael Crair, Merit Cudkowicz, Robin De Graaf, Daniel DiCapua, Mitchell Elkind, Carl Faingold, Susan Forster, Robert Fulbright, Karen Furie, Glenn Giesler, Darren Gitelman, Charles Greer, Stephen Grill, Noam Harel, Joshua Hasbani, Elizabeth Holt, Bahman Jabbari, Jason Klenoff, Igor Koralnick, Randy Kulesza, Robert LaMotte, Steven Leder, Ben Legesse, Robert Lesser, Albert Lo, Grant Lui, Steve Mackey, Andres Martin, Graeme Mason, Andrew Norden, Haakon Nygaard, Kyeong Han Park, Stephen Parker, Huned Patwa, Howard Pomeranz, Stephane Poulin, Sashank Prasad, Bruce Price, Diana Richardson, George Richerson, Anna Roe, David Russell, Robert Sachdev, Gerard Sanacora, Joseph Schindler, Michael Schwartz, Theodore Schwartz, Alan Segal, Nutan Sharma, Gordon Shepherd, Scott Small, Adam Sorscher, Joshua Steiner, Daryl Story, Ethan Taub, Kenneth Vives, Darren Volpe, Jonathan Waitman, Howard Weiner, Norman Werdiger, Michael Westerveld, and Shirley Wray.

Medical students contributed in an important way to this edition by helping me find new cases and images. Wenya Linda Bi, Alexander Park, April Levin, Matthew Vestal, Kathryn Giblin, Alexandra Miller, Joshua Motelow, and Amy Forrestel spent many early morning hours reviewing case materials for this book. Dragonfly Media Group contributed to art revisions, Picture Mosaics created the cover mosaic, Jean Zimmer provided copy editing, and Nathan Danielson helped draft the concept for the cover design.

Once again, I am very grateful to the entire staff of Sinauer Associates for their outstanding attention to high-quality publishing, and for their collaboration in all aspects of producing this book. I have enjoyed working on the Second Edition with Sydney Carroll, Graig Donini, Joan Gemme, Christopher Small, Jason Dirks, Linda VandenDolder, Marie Scavotto, Dean Scudder, and Andrew D. Sinauer. Having worked on two editions with Sinauer, I have an ever-deepening appreciation of the success of this group in producing excellent books.

## **Additional Acknowledgments for Third Edition**

As our journey continues, I again thank my family first for all their love, support, and inspiration. Sheltering in our home these past months with Michelle, my wonderful life partner, and our now adult or nearly adult children Eva,

Jesse, and Lev has been comforting in the face of challenging times in the world. I am also grateful to my dear parents, siblings and significant others Norma Grill, David Blumenfeld, Laura Blumenfeld, Baruch Weiss, Frances Blumenfeld, Bernard Grill (a'h), Leonard Kresch, Marsha Brody, Peter Brody, Adrienne Alexander, Michael Alexander, Rachel Brody, Michael Lustig, Barak Pearlmutter, Helena Smigoc, Nili Pearlmutter, Todd Bearson, Stephen Grill and Ellen Grill. Lifelong friends I won't enumerate by name complete the list of those most precious through the years.

In addition to those listed in the Acknowledgments for the First and Second Editions, I would like to thank the following colleagues for their excellent and highly informative chapter reviews: Hamada Altalib, Hardik P Amin, Nigel Bamford, Christopher Benjamin, Hilary Blumberg, Kenneth Blumenfeld, Richard Bronen, Joshua Brumberg, Gordon Buchanan, Zachary Corbin, Robin De Graaf, Kunal Desai, Jeffrey Dewey, George Dragoi, Mitchell Elkind, Hilary Fazzone, Arman Fesharaki-Zadeh, Adeniyi Fisayo, Robert Fulbright, Emily Gilmore, Darren R. Gitelman, Lauren Gluck, Christopher Gottschalk, Elena Gracheva, David Greer, Stephen Grill, Joshua Hasbani, David Heeger, Firas Kaddouh, Benison Keung, Babar Khokhar, Joshua Klein, Ninani Kombo, Igor Koralnik, Beth B. Krippendorf, Randy J. Kulesza, Alex Kwan, Maxwell Laurans, Jonathan Levitt, Steve Mackey, Graeme Mason, Matthew McGinley, Ana-Claire L. Meyer, Mario Monto, Elliot Morse, Maitreyi Murthy, Kumar Narayanan, Haakon Nygaard, Amar Patel, Kenneth Perrine, Patricia Peter, David Pitt, Howard Pomeranz, Amanda Redfern, George Richerson, Liana Rosenthal, Jarrett Rushmore, Arash Salardini, Lauren Sansing, Shobhit Singla, Joshua Steinerman, Jaideep S. Talwalkar, Ethan Taub, Sule Tinaz, Bertrand Tseng, Nick Turk-Browne, Susan Vander Morris, Phyllis E. Weingarten Kann, Norman Werdiger, and Michael Westerveld.

I am grateful to the following medical students who met with me weekly early in the morning to review new clinical cases for this edition: Irina Shklyar, Jose Gonzalez, Abhijeet Gummadavelli, Leisel Martin, Nathan Tu, Hilary Hanbing Wang, Mark Youngblood, Ningcheng (Peter) Li, Benjamin Lerner, Adam Kundishora, Hiam Naiditch, Rahiwa Gebre, John Andrews, Eric Chen, Prince Antwi, Neal Dolan, Swetha Dravida, and Natnael Doilicho. Swetha Dravida and Natnael Doilicho also contributed to updating the References. Art revisions were provided by the Dragonfly Media Group, Wendy Walker performed copy editing, and Thundercloud Consulting assisted with digital production of the e-book.

With the Third Edition, the excellent publisher Sinauer Associates has now become an imprint of another excellent publisher, Oxford University Press. Shortly after this transition, Sydney Carroll, who had worked with me on 1e and 2e, helped me see the importance of the Third Edition. I am very deeply grateful to all of the outstanding professionals at Sinauer Associates/Oxford University Press who have made working and collaborating on this new edition a true pleasure, including Jessica Fiorillo, Stephanie Nisbet, Karissa Venne, Jason Dirks, Joan Gemme, Beth Roberge, Michele Beckta, Linda VandenDolder, Lauren Cahillane, Morgan Delahunt, and Kathaleen Emerson. This incredible team demonstrates the value of true excellence in book publishing.

# *How to Use This Book*

The goal of this book is to provide a treatment of neuroanatomy that is comprehensive, yet enables students to focus on the most important “take-home messages” for each topic. This goal is motivated by the recognition that, while access to detailed information is often useful in mastering neuroanatomy, certain selected pieces of information carry the most clinical relevance, or are most important for exam review.

## **General Outline**

The first four chapters of the book contain introductory material that will be especially useful to students who have little previous clinical background. Chapter 1 is an introduction to the standard format commonly used for presenting clinical cases, including an outline of the medical history, physical examination, neuroanatomical localization, and differential diagnosis. Chapter 2 is a brief overview of neuroanatomy which includes definitions and descriptions of basic structures that will be studied in greater detail in later chapters. Chapter 3 builds on this knowledge by describing the neurologic examination. It includes a summary of the structures and pathways tested in each part of the exam, which is essential for localizing the lesions presented in the clinical cases throughout the remainder of the book. Much of the material in this chapter is also covered on the neuroexam.com website described below, which provides video demonstrations for each part of the exam. For readers who are unfamiliar with neuroimaging techniques, Chapter 4 contains a concise introduction to CT, MRI, and other imaging methods. This chapter also includes a Neuroradiological Atlas showing normal CT, MRI, and angiographic images of the brain. Chapters 5–19 cover the major neuroanatomical systems and present relevant clinical cases.

## **Chapters 5–19**

Chapters 5–19 have a common structure. An “Anatomical and Clinical Review” at the beginning of the chapters presents relevant neuroanatomical structures and pathways, and generously sized, carefully labeled color illustrations are used to vividly depict spatial relationships. The first part of each chapter also includes numbered sections called “Key Clinical Concept,” or “KCC,” which cover common disorders of the system being discussed.

**CLINICAL CASES** The second part of each chapter is a “Clinical Cases” section that describes patients seen by the author and colleagues, each presented in a numbered color box. Full-length cases include complete findings from the neurologic examination, while “Minicases” have a briefer format. Each case begins with a narrative of how the patient’s symptoms developed and what deficits were found on neurologic examination. For example, one

patient in Chapter 10 suddenly developed weakness in the right hand and lost the ability to speak. Another, in Chapter 14, experienced double vision and lapsed into a coma. Important symptoms and signs are indicated in boldface type. The reader is then challenged through a series of questions to deduce the neuroanatomical location of the patient's lesion and the eventual diagnosis.

A discussion follows each case, beginning with a summary of the key symptoms and signs. Answers to the questions are provided which refer to anatomical and clinical material presented in the first half of the chapter that is demonstrated by the case. One of the most exciting features of the book is the inclusion of large-format, labeled CT, MRI, or other scans that show the lesion for each patient, and serve as a central tool for teaching neuroanatomy. These images reveal, with striking clarity, both the lesion's location and the anatomy of the system being studied. In addition, these radiographs help the reader develop skill in interpreting the kinds of diagnostic images employed on the wards. The neuroimaging studies for each case are provided in special boxes at least one page turn away from the case questions, so the answers to the questions are not "given away" by the imaging (see below).

The clinical course is also provided for each patient and includes a discussion of how the patient was managed, and what outcome followed. Thus, by the end of each case, students learn the relevant material by application and diagnostic sleuthing rather than by rote memorization.

## Special Features for Focused Study and Review

The goal of students reading this book should be to read the material in depth. However, at times they may need to distill it down to the most clinically relevant points, or to focus on material most commonly on the national boards or other examinations. Therefore, several special features have been included to expedite focused study and review in both the print book and e-book (see next section):

- **Boldface type** is used rather differently than in most texts. In addition to identifying the text for all important topics and definitions, boldface is also used to facilitate rapid or focused reading.
- **Review Exercises** appear in the margins throughout the text, highlighting the most important anatomical concepts in each chapter, and providing practice exam questions.
- Helpful **mnemonics** are provided throughout the text, and these are flagged in the margins by a special icon (shown at right) displaying a section of the hippocampus (a structure important in memory formation).
- A **Brief Anatomical Study Guide** appears at the end of each chapter, which summarizes the most important neuroanatomical material, and refers to the appropriate figures and tables needed for focused exam review.
- The **Neuroradiological Atlas** in Chapter 4 also provides a useful review of neuroanatomical structures in three-dimensional space and can be used for reference and comparison to lesions seen in clinical cases.
- The **neuroexam.com** website includes much of the text from Chapter 3 describing the neurologic exam and its anatomical interpretation, and also features video demonstrations of each part of the exam that are cited in the text (e.g., "see **neuroexam.com Video 52**"). Selected video frames are also shown in the book margins, as demonstrated here, to illustrate relevant portions of the neurologic exam.

### REVIEW EXERCISE



Rapid hand movements  
[neuroexam.com](http://neuroexam.com) Video 52

- The **Key Clinical Concept (KCC)** sections provide a comprehensive introduction to clinical topics in neurology and neurosurgery and enable an efficient review of these topics.
- Finally, the **Clinical Cases** can be used by themselves for study and review, since they consist of anatomical puzzles that reinforce the subject matter for each chapter in the most clinically relevant context. As noted above, the neuroimaging studies for each case are deliberately placed at least one page turn away from the case questions; the location of the images for each case are indicated by page numbers provided immediately after the images are cited in the text.
- The **Additional Cases** section at the end of each chapter, and the **Case Index** at the end of the book provide further cases relevant to the topics in each chapter.

## e-book: Additional Features for Interactive Study and Review

The **Neuroanatomy through Clinical Cases e-book** (available through various e-book vendors including RedShelf, VitalSource, and Chegg) provides a highly interactive user experience, including the following additional enhanced features for study and review of neuroanatomy:

- **Interactive Figures** with drag and drop matching of labels to key anatomical structures.
- **Interactive Tables** with multiple-choice selection of key table entries.
- **Interactive Review Exercises** throughout chapters with brief quiz items on key content.
- **Active cross-reference links** for all figures and tables. These enable rapid cross-modality learning and review of visual and factual information throughout the book.
- **Videos** in the text link directly to streaming video on the [neuroexam.com](http://neuroexam.com) site.
- **Interactive cases** present thought-provoking questions with answers, clinical images, and outcomes in selectable show-hide format.
- **Interactive Review** section at the conclusion of each chapter includes the following:
  - List and links to all interactive items in the chapter.
  - Interactive Brief Anatomical Study Guide with additional quiz items covering all major chapter content.

## Suggested Course Use

*Neuroanatomy through Clinical Cases* is intended primarily for first- or second-year medical students enrolled in a course in neuroanatomy or neuroscience, but it is a versatile text that could be used in many settings.

The topics covered in the book include all neuroanatomical material required for the medical school board examinations. Although fundamental concepts are emphasized, some advanced subject matter is also provided. Because the book includes chapters on peripheral nerves, students will also find this book useful in their general gross anatomy course in which peripheral nerves are usually covered. The clinically and neuroanatomically oriented

presentation of neurologic exam skills in this book will be useful to student in both preclinical and clinical settings. The Key Clinical Concept sections in this book also cover the major neurologic and neurosurgical disorders at a level appropriate for medical school pathophysiology courses, clinical rotations, and residents early in their training.

Students of other health professions, especially physical therapy, occupational therapy, nursing, dentistry, speech therapy, and neuropsychology will find this textbook useful as well, and it may also be of interest to graduate students of neuroscience. In addition to those learning neuroanatomy, the cases in this book also serve as a resource for advanced medical students in their clinical rotations, and residents in neurology, neurosurgery, and neuroradiology seeking examples of “typical” cases of neurologic disorders. All relevant clinical details are included, while identifiers have been removed to maintain privacy and confidentiality. Because each case is a real patient, the clinical cases in this book are, in effect, a collection of case reports that can serve as a useful resource, especially for teaching purposes and board review. It should be noted, however, that the cases presented here are highly selected for their teaching value and do not constitute an unbiased sampling of the kinds of cases found in clinical practice.

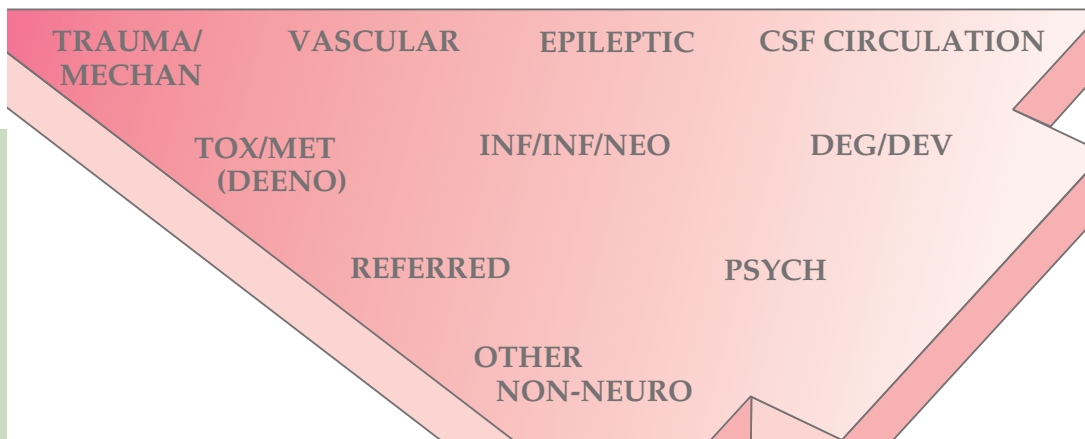
Here are some suggestions for using *Neuroanatomy through Clinical Cases* in various courses and curricula:

- For a comprehensive course in **medical school neuroanatomy**, students should read Chapters 2 and 5–18, with selected topics from Chapters 1, 3, 4, and 19. Reading assignments and large class lectures could focus on the Anatomical and Clinical Review sections at the beginning of each chapter. The clinical cases are most effectively discussed in small groups of students, where instructors can help students puzzle through the anatomical localization and diagnosis, and then discuss the neuroradiology and clinical outcome. An **Instructor’s Resource Library** is available which contains material that will be useful for lectures, and **additional clinical cases** not found in the book that are ideal for use in small group teaching.
- For medical school courses covering neuroanatomy and other topics in **neuroscience**, additional readings from neuroscience texts such as *Neuroscience* by Purves et al. (2017, Sinauer Associates, an imprint of Oxford University Press) or *Principles of Neural Science* by Kandel et al. (2021, McGraw-Hill) should be provided.
- For a comprehensive course in **clinical disorders of the nervous system**, students should read Chapters 3 and 4, and the Key Clinical Concept sections in Chapters 5–19. *The NeuroExam Video* should be viewed in class, and students referred to [neuroexam.com](http://neuroexam.com) for review. Clinical cases could then be presented in small groups, as described above.
- For a course focusing on **neuropsychological disorders** and anatomical correlations, students should read Chapters 2, 10, 18, and 19 and selected parts of Chapters 14 and 16.
- Finally, for a more **basic course in clinical neuroanatomy**, readings could be confined to selected topics in Chapters 2, 5–7, 10–16, and 18.



# Neuroanatomy through Clinical Cases

THIRD EDITION



## CONTENTS

### **Introduction 4**

### **The General History and Physical Exam 4**

- Chief Complaint (CC) 5
- History of the Present Illness (HPI) 5
- Past Medical History (PMH) 6
- Review of Systems (ROS) 6
- Family History (FHx) 6
- Social and Environmental History (SocHx/EnvHx) 6
- Medications and Allergies 6
- Physical Exam 6
- Laboratory Data 7
- Assessment and Plan 7

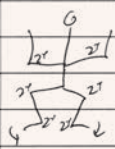
### **Neurologic Differential Diagnosis 7**

### **Relationship between the General Physical Exam and the Neurologic Exam 8**

### **Conclusions 10**

# Introduction to Clinical Case Presentations

Case presentations provide the framework for all communications about patient care. They lay down the basic information needed to formulate hypotheses about the location and nature of patients' problems. This information is then used to decide on further diagnostic tests or treatment measures. To diagnose and treat patients such as those described in this book, we must first learn how clinicians generally present a patient's medical history and the findings from their physical examination. In addition, we must learn how to formulate ideas about neurologic diagnosis and how the neurologic evaluation fits into the general context of patient assessment.

DATE	TIME	
12/1/93	6 <sup>00</sup> pm	<p><u>Neurology EW JR</u></p> <p><u>ce:</u> Asked to eval 34♀ w/ nuchal rigidity, r.e. LP</p> <p><u>HPI:</u> Pt. w/ the TB Rxed XGnos, 7/11 w/ risk factors, c/o ~ 1 wk malaise, N/V, SOB + HA. → EW today w/ initial assessment was notable for nuchal rigidity, photophobia + CXR w/ diffuse patchy opacities. During CXA she had a GTC Se but then slowly awake + was responsive + appropriate but in resp distress ∴ intubated + no paralytics for sedation. Head CT showed mild ventriculomegaly c/w communicating hydroceph, + ? @ temporal hypodensity. Was asked to eval. pt. r.e. ? safety of LP. Pupils were reportedly <u>PEREC</u> on initial assessment. N Amp/Ceftriaxone started.</p> <p><u>PE:</u> Thin young ♀ intubated sedated P144 BP 114/72 T100 + pt. breathing spontaneously</p> <p>~ 4<sup>05</sup> pm <u>Initial exam:</u> <u>Unresponsive</u></p> <p>⊙ pupil 5mm → 3mm sluggish fundi - nt. bilat  ⊙ pupil 8mm irreg. unresponsive  ⊙ EOMs ⊕ oculobulbar (HE) corneal reflex ⊕  ⊙ grimace, ⊕ cough/gag  ⊕ spontaneous munts. all 4's, but no urinal + pain</p> <p>(Cont'd) →</p>
		

## Introduction

**N**EUROANATOMY is one of the more clinically relevant courses taught in the first years of medical school. Principles learned in neuroanatomy are directly applicable to patient care, not just for the neurologist or neurosurgeon, but also for health care professionals in virtually every other field. However, medical students in their first years and other students of neuroanatomy are often unfamiliar with the basic principles of clinical case presentations used on the wards. Therefore, the first section of this chapter has been provided for the *nonclinician* or the *not-yet-clinician* as a brief orientation. Others may prefer to skip this section. The second section of this chapter discusses the neurologic differential diagnosis, a process through which several possible diagnoses are considered based on the available information. We will use this method when attempting to arrive at diagnoses in the cases throughout the remainder of the book.

Abbreviations will be avoided in the case presentations in this book whenever possible, although in reality they are used quite often on the wards. Therefore, some commonly used abbreviations will be introduced in this chapter.

The neurologic exam is only one part of the general physical exam. Nevertheless, the patient should always be treated as a whole and, in addition, much can be learned about neurologic illness from other parts of the physical exam. Therefore, in the final section of this chapter we will discuss the dynamic relationship between the general physical exam and the neurologic exam.

## The General History and Physical Exam

While there are variations in personal styles, clinicians adhere to a fairly standard format when presenting cases so that all of the essential information can be succinctly communicated. Since this may be your first exposure to this format, we will first discuss the general structure of the history and physical examination that is used in all fields of medicine. Although the basic structure is always the same, the emphasis varies depending on the specialty. Therefore, in Chapter 3 we discuss the neurologic part of the physical exam in more detail. Note that case presentations in this book focus on the neurologic history and physical exam, although it is crucial to treat the patient as a whole and to never neglect symptoms and signs arising from other body systems. In addition, as described in the discussion that follows, certain features of the general physical exam often provide important information about neurologic illness.

One of the most daunting tasks confronting medical students as they first enter the wards is to master the art of case presentations. When a new patient is admitted to the hospital, it is the responsibility of the medical student and resident on call to obtain a good history and physical exam (H&P) and then to communicate this knowledge to the other members of the medical team. These skills are continually refined throughout a clinician's career as they see more patients.

The level of detail used in obtaining an H&P depends on both the setting and the patient. For example, the appropriate H&P when caring for an unfamiliar patient with multiple, active medical problems is much more detailed than the H&P for a familiar patient who is generally healthy and comes to the outpatient office with an injured finger. As a student's clinical skills develop, the H&P becomes a highly focused tool used both to investigate clinical problems of immediate concern and to screen for other potential problems that may be suspected on the basis of the overall clinical picture.

Remember that the whole point of the H&P is to *communicate*. The goal is to present the important points of the case to one's colleagues in the form of an interesting "story." They can then contribute to the patient's care through

discussion of the case or by taking care of the patient in the middle of the night when the people who originally admitted the patient may be sound asleep at home. As one learns more clinical medicine, one gradually comes to know the difference between critical details not to be overlooked and irrelevant side issues that put listeners to sleep. This distinction is often surprisingly subtle, but it makes all the difference in effective case presentations.

The general format most commonly used for an H&P contains the following elements, which we will discuss in more detail in the sections that follow:

- Chief complaint, or why the patient now requires care
- History of the present illness
- Past medical history
- Review of systems
- Family history
- Social and environmental history
- Medications and allergies
- Physical exam
- Laboratory data
- Assessment and plan

### **Chief Complaint (CC)**

This is a succinct statement that includes the patient's age, sex, and presenting problem. It may also include one or two very brief pieces of pertinent historical data.

**Example:** "The patient is a 53-year-old man with a history of hypertension now presenting with crushing substernal chest pain of 1 hour's duration."

### **History of the Present Illness (HPI)**

This is the complete history of the *current* medical problem that brought the patient to medical attention. It should include possible risk factors or other causes of the current illness as well as a detailed chronological description of all symptoms and prior care obtained for this problem. Pertinent negative information (symptoms or problems that are *not* present) helps exclude alternative diagnoses and is as important as pertinent positive information. Related medical problems can be mentioned as well; however, those that are not directly relevant to the present illness are usually covered instead in the section on past medical history (discussed in the next section).

**Example:** "The patient has cardiac risk factors consisting of hypertension for 15 years and a family history of coronary artery disease. He does not smoke, nor does he have diabetes or elevated cholesterol. He has not had previous myocardial infarction. For the past 5 years he has had a stable pattern of chest pain on exertion, brought on by walking up two or more flights of stairs, lasting less than 5 minutes, not accompanied by other symptoms. The pain is relieved by rest and sublingual nitroglycerin. He has refused to undergo further cardiac workup, such as exercise stress testing, in the past. He denies symptoms of congestive heart failure and has no history of peripheral vascular or cerebrovascular disease. Today while sitting at his desk at work, he developed sudden 'crushing' substernal chest pain and pressure radiating to his neck, accompanied by tingling of the left arm, shortness of breath, sweating, and nausea without vomiting. The pain was not relieved by three sublingual nitroglycerin tablets, and his coworkers called an ambulance to bring him to the emergency room, where he was afebrile with pulse 100, BP 140/90, and respiratory rate 20, and had an EKG with ST elevations, suggesting anterolateral myocardial ischemia. His pain

was initially relieved by IV nitroglycerin and 2 mg of morphine, but then returned, lasting over 20 minutes with continued ST elevations. He is now being admitted for urgent cardiac catheterization.”

### ***Past Medical History (PMH)***

Prior medical and surgical problems not directly related to the HPI are described here.

**Example:** “The patient has a history of a mildly enlarged prostate gland. He had a right inguinal hernia repair in 1978.”

### ***Review of Systems (ROS)***

A brief, head-to-toe review of all medical systems—including head, eyes, ears, nose and throat, pulmonary, cardiac, gastrointestinal, genitourinary, OB/GYN, dermatologic, neurologic, psychiatric, musculoskeletal, hematological, oncologic, rheumatological, endocrine, infectious diseases, and so on—should be pursued to pick up problems or complaints missed in earlier parts of the history. If something comes up that is relevant to the HPI, it should be inserted in the HPI section, not buried in the ROS.

**Example:** “The patient has had mild upper respiratory symptoms for the past 4 days with nasal congestion but no cough, temperature, or sore throat.”

### ***Family History (FHx)***

This section should list all immediate relatives and note familial illnesses such as diabetes, hypertension, asthma, heart disease, cancer, depression, and so on, especially those relating to the HPI. Family tree format is often a succinct and clear way to present these data.

**Example:** “Patient’s mother died at 64 of myocardial infarction, had hypertension. Father had myocardial infarction at 52, had diabetes, died at 73 of stroke. Brother, 47 years old, healthy. Two children, healthy.”

### ***Social and Environmental History (Sochx/EnvHx)***

This section should include the patient’s occupation, family situation, travel history, sexual history (if not covered in ROS), and other relevant habits.

**Example:** “Electrical engineer. Married with two children. No recent travel. Denies ever smoking cigarettes or using drugs. Drinks 1–2 beers on Sundays.”

### ***Medications and Allergies***

This section should list all medications currently being taken by the patient (including herbal or over-the-counter drugs), as well as any known general or drug allergies.

**Example:** “Lisinopril 20 mg PO daily. Metoprolol 100 mg PO daily. Sublingual nitroglycerin as needed. No allergies. NKDA (no known drug allergies).”

### ***Physical Exam***

The examination generally proceeds from head to toe and includes the following sections:

- General appearance—for example, “A diaphoretic man in clear discomfort.”
- Vital signs—temperature (T), pulse (P), blood pressure (BP), respiratory rate (R)
- HEENT (head, eyes, ears, nose, and throat)
- Neck

- Back and spine
- Lymph nodes
- Breasts
- Lungs
- Heart
- Abdomen
- Extremities
- Pulses
- Neurologic (see Chapter 3)
- Rectal
- Pelvic and genitalia
- Dermatologic

### **Laboratory Data**

This comprises all diagnostic tests, including blood work, urine tests, electrocardiogram, and radiological tests (chest X-rays, CT scans, etc.).

### **Assessment and Plan**

The **assessment** section usually begins with a one- or two-sentence **summary**, or **formulation**, that encapsulates the patient's main clinical features and most likely diagnosis. In more diagnostically uncertain cases, a brief discussion is added to the assessment, including a **differential diagnosis**—that is, a list of alternative possible diagnoses. With neurologic disorders, this discussion is often broken down into two sections: (1) localization and (2) differential diagnosis.

The **plan** section immediately follows the assessment and is usually broken down into a list of problems and proposed interventions and diagnostic procedures.

**Example:** “This is a 53-year-old man with cardiac risk factors of hypertension and family history of coronary disease who presents with substernal chest pain and EKG changes suggestive of anterolateral wall myocardial infarction.

1. Coronary artery disease: Patient to undergo cardiac catheterization for diagnosis and treatment including angioplasty/stenting as needed. Admit post-procedure to cardiac intensive care unit for further care. Will check serial EKGs and cardiac enzymes to determine whether the patient has had a myocardial infarction.
2. Further cardiac workup: To include echocardiogram and an exercise stress test if cardiac enzymes and catheterization are negative. Resume prior medications and follow up as outpatient.”

## **Neurologic Differential Diagnosis**

Reaching the correct diagnosis in patients with neurologic disorders sometimes presents a considerable challenge. As noted in the previous discussion, the assessment section of the H&P is therefore often broken down into several logical steps to facilitate this thought process. The first step is **localization** based on neuroanatomical clues gleaned from the H&P. This integration of anatomical and clinical knowledge will be the focus of this book. However, we will also briefly discuss the next step, the **neurologic differential diagnosis**.

When the diagnosis is uncertain and multiple possibilities must be considered, it is often helpful to have a mnemonic device handy, especially while being questioned on rounds by a more senior clinician. Such a mnemonic, the Arrowhead of Neurologic Differential Diagnosis, is shown in **Figure 1.1**. Disorders that tend to be more acute and require more immediate attention



- MRI axial FLAIR image, 873f  
 MRI axial T1-weighted image, 108f, 553f, 559f, 603f, 693f  
 MRI axial T2-weighted image, 667f, 679f, 680f  
 MRI coronal image, 114f, 732f  
 MRI diffusion-weighted image, 669f  
 MRI sagittal image, 116f, 199f, 308f, 312f, 560f, 611f, 693f  
 in myelin-stained section, 622f  
 in pain modulation, 280, 280f  
 in respiratory control, 648, 649f  
 rostral. *See* Rostral medulla  
 sagittal view in situ, 701f  
 and serotonergic projection systems, 637f  
 sleep-promoting regions in, 639  
 and somatosensory system, 35f, 275f, 276f, 288f, 289, 289f  
 surface anatomy of, 26f, 498f, 499, 499f  
 and trigeminal sensory system, 512f  
 vascular syndromes of, 658t, 658–659, 663–666, 667f–669f  
 in vertebrobasilar ischemia, 657  
 and weakness patterns, 241f, 242f, 243f, 244f, 245f, 246f, 247
- Medullary lamina  
 external, 745f, 749f  
 internal. *See* Internal medullary lamina  
 lateral, 829f  
 medial, 829f
- Medullary pyramids, 230f, 233
- Medullary reticular formation, 236f, 622f, 695
- Medullary reticulospinal tract, 236f, 279f
- Medullary velum, 39f, 498f, 620f, 701f
- Medulloblastoma, 158, 158t, 159
- Melanoma, 159
- Melanopsin, 800
- Melatonin, 642
- Membranous labyrinth, 521, 522f
- Memory, 824, 825, 825t, 833–849, 881  
 age-related changes in, 849  
 in Alzheimer's disease, 848, 941, 973–974, 977f  
 amygdala in, 851  
 assessment of, 53, 54, 844–845, 889  
 attention and consciousness in, 945  
 cellular mechanisms in, 844t  
 classification of, 843f, 843–844  
 cognitive models of, 845–846  
 consolidation of, 844t, 845  
 context-dependent, 846  
 in dementia, 934  
 differential diagnosis in loss of, 846–849, 847t  
 in disconnection syndromes, 905–906  
 disorders of, 842–849, 865–871, 882  
 frontal lobe in, 916, 918, 918t  
 hippocampal formation in, 825, 825t, 833–849, 882  
 olfactory, 833, 851  
 of patient H.M., 842–843, 844, 845, 845f, 846  
 recent, 54, 844–845  
 remote, 54, 845  
 Wada test of, 100, 859, 905–906  
 working, 844, 844t, 916
- Ménière's disease, 531
- Meningeal artery, middle, 131, 132f, 148
- Meningeal layer of dura, 126f, 130
- Meninges, 16, 126f, 129–131, 132  
 sensation from, 540  
 signs and symptoms in  
 irritation of, 160, 160t
- Meningioma, 158, 158t, 159  
 of foramen rotundum, 543–544, 546f  
 frontal lobe in, 964, 969f  
 optic chiasm in, 473, 481, 482f  
 pons in, 557–558, 560f–561f  
 pseudobulbar affect in, 557–558, 560f–561f  
 spinal cord in, 303–305, 306f
- Meningitis, 160–163, 212–213  
 aseptic, 161t, 162–163, 163t, 164  
 bacterial, 160–161, 161t, 212–213  
 fungal, 160, 165, 166  
 headache in, 141  
 lymphocyte-predominant, 162–163, 163t, 164, 168  
 mental status changes in, 939  
 neoplastic or carcinomatous, 169  
 signs and symptoms in, 160, 160t  
 viral, 160, 161t, 164
- Meningoencephalitis, herpes simplex, 161t, 164, 165
- Meningovascular syphilis, 163
- Mental status, 51t, 52–58, 888–889, 889t  
 acute disorders of, 931–934  
 chronic disorders of, 932, 933, 934–941  
 in coma, 74t, 75–76  
 in delirium, 932–934  
 in dementia, 934–941  
 in frontal lobe disorders, 918t, 918–920  
 in hydrocephalus, 157, 938  
 in intracranial pressure increase, 143  
 and level of consciousness, 40–41, 41f, 53, 75–76  
 in screening exam, 81t  
 subacute changes in, 933t
- Meralgia paresthetica, 365, 379, 379f
- Mesencephalic trigeminal nucleus, 512f, 513, 562, 625  
 in functional columns of brainstem, 503f  
 functions of, 511t  
 in myelin-stained sections, 619f, 620f
- Mesencephalic trigeminal tract, 512f, 513, 619f, 620f, 625
- Mesencephalon, 14, 15, 15f, 796f
- Mesenteric ganglion, 238f
- Mesial temporal sclerosis, 859–860
- Mesocortex, 827, 828t
- Mesocortical pathway, 635f, 636
- Mesolimbic pathway, 635f, 636
- Mesostriatal pathway, 635f, 635–636
- Metabolic disorders, 859, 933t, 934
- Metamorphopsia, 924
- Metastatic tumors, 158, 159  
 of bladder, 335, 337f  
 of colon, 956, 960f  
 of lung, 159, 723–724, 729f, 729–730, 732f
- Metencephalon, 15, 15f
- Meyer's loop, 465, 465f, 474f, 477
- M-group of neurons in eye movements, 589
- Microadenoma of pituitary, 804, 805, 806
- Microaneurysms of Charcot–Bouchard, 154
- Micrographia in Parkinson's disease, 766
- Micropsia, 924
- Micturition centers, 292f, 294, 915f
- Midbrain, 14, 15, 15f  
 and anterolateral somatosensory pathways, 276f  
 in axial section, 617f, 619f  
 blood supply of, 653, 653f, 654f, 657, 662t, 662–663  
 as brainstem structure, 38f, 39f, 41f, 497, 561, 617, 619f  
 caudal, 619f  
 CT image, 177f, 178f, 184f, 193f, 417t, 443f, 691f, 958f  
 and descending motor pathways, 232f, 234f, 235f, 236f  
 in horizontal section, 232f  
 infarction of, 676, 680f–681f, 684–685, 687, 688f–689f, 691f  
 lateral view, 701f  
 midsagittal view, 496f  
 MRI axial image, 421f, 484f, 546f, 680f, 827f, 868f, 954f  
 MRI coronal image, 114f  
 MRI diffusion-weighted image, 669f  
 MRI sagittal image, 116f, 199f, 560f, 611f  
 in myelin-stained section, 619f  
 in pain modulation, 280f  
 in pathologic specimen, 188f  
 and posterior column somatosensory pathway, 275f  
 reticular formation in, 131f, 571f, 589, 619f, 631f, 654f  
 and rubrospinal tract, 234f  
 and serotonergic projection systems, 637f  
 surface anatomy of, 26f, 27f, 497, 498f, 499f  
 tegmentum of, 15f, 104f, 662, 662t, 689f  
 and tentorial incisura, 130  
 and trigeminal sensory system, 512f  
 vascular syndromes of, 662t, 662–663  
 in vertebrobasilar ischemia, 657
- Midbrain corectopia, 584
- Midbrain–diencephalic junction, 15f, 16, 496f, 497
- Middle cerebellar peduncle, 38f, 39f, 628, 702, 735  
 in axial section, 654f, 655f  
 and deep cerebellar nuclei, 703f  
 dorsal view, 702f  
 lateral view, 701f  
 lung adenocarcinoma metastasis to, 729–730, 732f  
 MRI axial image, 109f, 674f, 732f, 736f  
 MRI coronal image, 114f, 732f
- MRI normal image, 736f  
 MRI sagittal image, 116f  
 in myelin-stained section, 620f, 621f  
 surface anatomy of, 498f, 499, 499f  
 ventral view, 702f
- Middle cerebral artery, 45f, 46, 131, 391, 391f, 392, 396f, 453  
 aneurysm of, 149, 152f  
 angiography of, 118f, 417f–419f, 434, 441f–442f, 446f  
 angiography of, lateral view, 488f, 596f  
 and circle of Willis, 392f  
 clinical syndromes of, 398t–399t, 398–400  
 in coronal section, 748f, 828f  
 cortical branches, 118f, 120f, 297, 394f, 441f  
 cortical branch occlusion, 253, 255–259, 260f  
 CT angiography, 434, 440f  
 CT image, 89f, 428, 430, 431f, 432f, 434, 443f–444f  
 deep territory, 397f, 453  
 infarction of. *See* Middle cerebral artery infarction  
 inferior division, 393–394, 394f, 395f, 397f, 453, 898f  
 insular (Sylvian) branches, 118f, 120f, 394f  
 and lenticulostriate arteries, 395f  
 M1 segment, 118f, 120f  
 MRA image, 120f, 674f  
 MRI axial image, 110f, 429f, 448f, 827f, 954f  
 MRI coronal image, 96f, 115f, 448f, 559f  
 MRI sagittal image, 116f–117f  
 opercular branches, 118f, 120f, 394f, 441f  
 segments and branches of, 392  
 stem, 309  
 superior division, 393–394, 394f, 395f, 397f, 453, 898f  
 vascular territory of, 393–394, 394f, 401f, 453, 476, 898f  
 watershed zones, 118f, 400–401, 401f, 444–445, 448f, 477, 898f, 901
- Middle cerebral artery infarction, 297, 398–400, 407, 425–440  
 in ACA–MCA watershed, 400–401, 444–445, 448f, 901  
 Broca's aphasia in, 425–426, 897, 898, 948–950, 952f  
 CT image, 256f–257f, 431f, 965f  
 deep territory, 398t, 399t, 430, 432f  
 disconnection syndromes in, 905, 905f  
 hemispherectomy in, 407, 440, 447f  
 hemineglect in, 436–440, 446f–447f, 912f, 961–963, 965f  
 inferior division. *See* Inferior division MCA infarction  
 lacunar, 400, 430, 432f  
 in MCA–PCA watershed, 400–401, 901  
 MRI image, 429f, 952f, 954f  
 precentral gyrus face area in, 255–259, 260f

- precentral gyrus hand area in, 253–254, 256f–257f  
stem, 398f, 399t, 432–435, 438–440, 440f–444f, 447f  
superior division. *See* Superior division MCA infarction  
transcortical aphasia in, 901  
Wernicke's aphasia in, 427–428, 899
- Middle cerebral veins, 410, 410f  
Middle cervical ganglia, 236  
Middle cranial fossa, 127f, 128–129, 501f, 521f  
  contents of, 128, 129f, 131f  
  CT image, 210f  
Middle ear, 128f, 521, 521f, 549f  
Middle frontal gyrus, 25, 26f, 27f  
  in attention, 928f  
  CT image, 104f, 105f, 106f  
  MRI image, 112f, 115f, 298f, 869f  
  three-D surface reconstruction, 97f  
Middle hypothalamic region, 798f, 799, 799f, 819, 829f  
Middle meningeal artery, 131, 132f, 148  
Middle temporal gyrus, 25, 26f, 114f  
Middle trunk of brachial plexus, 356f  
Midget cells, 462, 463, 468f, 492  
Midline shift of brain structures, 142  
Midline thalamic nuclei, 37f, 281, 281f, 283t, 632t, 633  
Midsagittal section, 17  
Migraine headache, 139–140  
  in arteriovenous malformations, 485–486, 487f–488f  
  complicated, 140  
  fortification scotoma in, 139, 472  
Mild cognitive impairment, 935  
Millard-Gubler syndrome, 660t, 661  
Minimally conscious state, 643t, 644f, 645  
Miosis, 584  
  in Horner's syndrome, 140, 582, 600–601, 603f  
Mitral cells, 832, 832f, 881  
Mixed spinal nerves, 319  
M net magnetization in MRI, 90, 91f  
Molaison, Henry Gustav, 842–843  
Molecular layer  
  of cerebellar cortex, 704f, 705, 705f  
  of dentate gyrus, 834, 835f  
  of hippocampus and subiculum, 835, 835f  
Monocular vision disorders, 471, 473  
Mononeuropathy, 326  
Monosynaptic pathway of  
  hippocampal formation, 838, 882  
Monosynaptic stretch reflex, 37, 37f  
Mood, assessment of, 58  
Morton's metatarsalgia, 365  
Mossy fibers, 704f, 705, 705f, 706f, 707, 735, 835f, 838  
Motor aphasia, 43  
Motor axons in stretch reflex, 37f  
Motor channel, 754, 754f, 754t, 790  
Motor columns of cranial nerve nuclei, 503, 504t, 561  
Motor cortex, 222–224, 223f, 224f  
  association, 222, 228, 708f, 890f  
  and cerebellar output pathways, 708f  
  and corticospinal tract, 33f  
  and homunculus, 224f  
  primary. *See* Primary motor cortex  
  supplementary. *See* Supplementary motor area  
  and thalamus connections, 285f  
  weakness patterns in lesions of, 243–244, 246, 247  
Motor exam, 51t, 63–65  
  at bedside, 248  
  in coma, 74t, 77  
  in neglect, 910–912  
  in screening, 81t  
Motor extinction, 910  
Motor homunculus, 28, 29f, 222, 224f  
Motor impersistence, 57, 73, 931  
Motor neglect, 56, 73, 909, 909t, 910–912  
Motor nerve roots, 22, 22f, 23, 226f, 267, 318f, 319, 349  
  and basic spinal cord anatomy, 224, 225f  
  and somatic efferents, 237f  
  in stretch reflex, 37f  
Motor neurons, 33–34, 252  
  alpha, 228  
  and basic spinal cord anatomy, 224, 225f  
  beta, 229  
  gamma, 228  
  lower. *See* Lower motor neurons  
  in stretch reflex, 37f, 38  
  upper. *See* Upper motor neurons  
  and ventral nerve roots, 224  
Motor nuclei, 225t, 624  
  in brainstem, 617  
  branchial, 504, 504t, 624  
  lateral, 225f, 226f  
  medial, 225f, 226f  
  in myelin-stained section, 623f  
  somatic, 624  
  trigeminal, 503f, 504, 504t, 510f, 514, 620f, 624  
  of vagus nerve. *See* Dorsal motor nucleus of vagus nerve  
Motor root of trigeminal nerve, 501f, 510, 510f, 514, 562  
Motor system, 32–34, 221–268  
  assessment of, 51t, 63–65, 77, 81t  
  basal ganglia in, 34, 34f, 228, 228f, 754, 754t, 790  
  brainstem in, 228f, 229, 649–650  
  cerebellum in, 34, 34f, 228, 228f, 700, 703t  
  in coma and related states, 643t, 644f  
  and coordination of movements, 68–70  
  corticospinal tract in, 32–33, 33f  
  descending pathways in, 32–33, 229, 233, 234f–236f  
  frontal lobe disorders affecting, 920  
  and gait, 70–71  
  general organization of, 228f, 228–230  
  long tracts in, 222, 222t, 274t  
  in multiple sclerosis, 251t  
  pathways in, 32–34, 33f, 228  
  and planning of movements, 43–44  
  somatotopic organization of, 229f  
  spinal cord in, 286  
  topographic organization of, 28, 29f  
Motor tics, 761, 762  
Motor unit, 367  
Movement  
  assessment in motor exam, 64  
  coordination in, 68–70  
  in gait, 70–71  
  planning of, 43–44  
  rapid alternating, 69  
  unconscious, in psychogenic paralysis, 80  
Movement disorders, 757–771  
  cerebellar exam in, 718, 757  
  contralateral to basal ganglia lesion, 758  
  deep brain stimulation and stereotactic ablation in, 772–773  
  in Huntington's disease, 34, 742, 753, 760, 770–771, 775  
  hyperkinetic, 34, 742, 753, 789, 863  
  hypokinetic, 34, 742, 758, 789, 790  
  in Parkinson's disease, 753, 763, 765, 766  
  Movement perception, 467–468, 468f, 492  
M pathway, 464  
MPTP exposure, 769  
Mucormycosis, 167  
Müller's muscle, 580–581, 584  
Multi-infarct dementia, 938  
Multiple sclerosis, 250–251, 251t, 308–309  
  horizontal diplopia in, 605–606, 608f  
  oligoclonal bands in, 169, 251  
  optic neuritis in, 251, 477–478, 479–480  
Multiple subpial transection, 862  
Multiple system atrophy, 768  
Multipolar neurons, 17  
Munchausen syndrome, 79  
Muscarinic cholinergic receptors, 237, 635  
Muscles  
  common disorders of, 328  
  corticospinal tract to, 33f, 33–34, 230f  
  electromyography of, 252, 327, 367, 762  
  function testing, 64  
  of hand, 360t, 360–361  
  inspection of, 64  
  palpation of, 64  
  recruitment pattern of motor unit, 367  
  and spinal nerve roots, 322, 323t–325t  
  strength testing, 64–65, 65t–66t, 80  
  stretch reflex, 37f, 37–38  
  tone of, 63t, 64, 239, 239t, 721  
  weakness in disorders of, 246, 247  
Muscle specific receptor tyrosine kinase antibodies, 328  
Muscle spindles, 37, 37f, 228  
Musculocutaneous nerve, 358  
  and brachial plexus, 356f, 357, 357f  
  functions of, 323t, 358t, 385  
Musical hallucinations, 926, 972–973, 976f  
Musician's cramp, 759  
Mutism, akinetic, 75, 643t, 644f, 646, 758  
Myasthenia gravis, 327–328, 379–381, 383f  
  nerve conduction studies in, 367, 381, 383f  
  ptosis of eyelid in, 327, 379–381, 585  
Mydriasis, 584  
Myelencephalon, 15, 15f  
Myelin sheath, 18f, 19  
Myelin-stained brainstem sections, 617, 619f–623f  
Myelitis, 288, 307–309, 310f  
  transverse, 165, 251  
Myelography, 88  
  computed tomography, 88–89, 331, 350f–351f  
  in lumbar radiculopathy, 343, 346f  
Myelopathy, 287  
Myerson's sign, 68, 766, 920–921  
Myocardial infarction, 403, 407  
Myoclonic epilepsy, juvenile, 860  
Myoclonus, 719, 762  
  in Creutzfeldt–Jakob disease, 167, 762  
  palatal, 764  
Myopathies, 328, 367  
Myositis, 328  
Myotomes, 322, 349  
Myxedema coma, 807
- ## N
- Naming tasks, 54, 897t  
  in Broca's aphasia, 897  
  in classification of aphasias, 900, 902  
  in dysnomia, 901–902, 903  
  in Wernicke's aphasia, 899  
Narcolepsy, 636, 642  
Nasal turbinates, 542f  
Nasolabial fold, subtle decrease in, 248  
Nausea, 139, 140, 143, 650  
Near response of pupils, 59, 60  
Neck  
  examination of, 9  
  muscles of, 102f, 108f, 160, 160t  
  nuchal rigidity in meningitis, 160, 160t  
Necrotizing myopathy, 328  
"Negative myoclonus," 762  
Neglect, 44, 908–913  
  conceptual, 909, 909t, 912–913  
  hemineglect. *See* Hemineglect  
  motor, 56, 73, 909, 909t, 910–912  
  neurologic exam in, 56, 73  
  sensory, 56, 73, 909t, 909–912  
Neighborhood effects, 14  
Neisseria meningitidis meningitis, 161t  
Neocortex, 827, 828t  
  cell layers of, 29t, 29–30, 30f, 882  
  in memory, 845

- Neologisms, 54, 899
- Neoplasms  
 back pain in, 329t  
 in brachial plexus region, 367–369, 370f  
 of brain. *See* Brain tumors  
 CT image, 88  
 hearing loss in, 528–529  
 lymphoma. *See* Lymphoma  
 meningitis in, 169  
 metastatic. *See* Metastatic tumors  
 optic chiasm compression in, 473, 481, 482f  
 paraneoplastic syndromes in, 159–160  
 of pineal gland, 159, 195–200, 590, 606–607, 611f  
 pituitary adenoma, 158, 159, 804–807, 809–812  
 radiculopathy in, 331, 332, 335, 337f  
 schwannoma. *See* Schwannoma  
 spinal cord compression in, 287, 303–305, 306f  
 superior sagittal sinus thrombosis in, 449–450, 451f–452f  
 vertigo in, 531
- Neostriatum, 742, 742t
- Nephrogenic diabetes insipidus, 807, 808
- Nerve cells, 17–19. *See also* Neurons
- Nerve conduction studies, 365–367, 366f  
 in botulism, 367, 384  
 in Guillain-Barré syndrome, 382  
 in myasthenia gravis, 367, 381, 383f  
 repetitive stimulation testing in, 366, 381, 383f  
 of ulnar nerve, 366f, 373, 381
- Nervus intermedius, 515, 516f, 521f
- Net magnetization *M* in MRI, 90, 91f
- Neural foramen, intervertebral, 319, 320f, 329t, 350
- Neuralgia  
 glossopharyngeal, 537  
 occipital, 335  
 trigeminal, 140, 141, 514
- Neural tube, 14
- Neurapraxia, 326
- Neuritis  
 optic, 59, 251, 477–478, 479–480  
 vestibular, 531
- Neuroangiography, 98f, 98–100, 118f–122f
- Neurocognitive disorder, HIV-associated, 165, 939
- Neurodegenerative disorders, seizures in, 859
- Neuroendocrine system, 850–851
- Neuroendoscopy, 170  
 in hydrocephalus, 157, 170, 198, 205, 207f–208f
- Neurofibrillary tangles in Alzheimer's disease, 939, 974, 977f
- Neurofibroma, 332
- Neurogenic bladder, 295
- Neurogenic claudication, 331
- Neurogenic diabetes insipidus, 807, 808
- Neurohypophysis. *See* Posterior pituitary
- Neurologic examination, 48–82. *See also* Assessment of patient
- Neuroma  
 acoustic, 528–529, 531, 550–551, 553f  
 trigeminal, 529, 544–545, 547f–548f
- Neuromodulation, 19, 633, 634, 713
- Neuromuscular junction, 327–328, 366–367
- Neurons, 17–19, 18f  
 aspiny, 753  
 inhibitory spiny, 752  
 motor. *See* Motor neurons  
 sensory. *See* Sensory neurons
- Neuropathy, 326–327, 362–365  
 acute inflammatory demyelinating, 326–327, 381–382  
 distal symmetrical polyneuropathy, 289f, 290, 326  
 electromyography in, 367  
 of femoral nerve, 361t, 364, 375, 375f  
 mechanical causes of, 326  
 of obturator nerve, 361t, 365  
 of optic nerve, anterior ischemic, 476  
 of peroneal nerve, 361t, 365, 377, 377f  
 region of sensory loss in, 361t  
 of sciatic nerve, 361t, 364–365, 375–377, 376f, 378f
- Neuropsychology testing, 888, 935
- Neuroradiology, 85–122. *See also specific techniques.*  
 angiography in, 98–100  
 computed tomography in, 86–90  
 functional imaging in, 100–101  
 imaging planes in, 17, 86  
 interventional, 99–100  
 magnetic resonance imaging in, 89–96
- Neurostimulation, 772–773, 861–862
- Neurosurgery  
 craniotomy in, 169–170, 196f  
 endoscopic, 157, 170, 198, 205, 207f–208f, 805  
 stereotactic. *See* Stereotactic procedures
- Neurosypphilis, 163, 165, 939
- Neurotransmitter receptors, 18f, 19, 20t, 632t
- Neurotransmitters, 18f, 19–21, 632t, 633–638  
 actions of, 20t, 632t  
 in autonomic nervous system, 237
- Niacin deficiency, 939
- Nicotinic cholinergic receptors, 237, 635
- Nigrostriatal pathway, 635f, 635–636, 750
- NIH Stroke Scale, 406
- Node of Ranvier, 18f, 19
- Nodose vagal ganglion, 536
- Nodulus of cerebellum, 621f, 701, 702f, 703f
- Noise suppression in attention, 927
- Noncommunicating hydrocephalus, 156
- Noncontrast CT scans, 88
- Nondeclarative memory, 843f, 843–844
- Nondominant cerebral hemisphere, 44, 906–913, 977  
 functions of, 892, 892t  
 in language processing, 895–896  
 in spatial analysis, 906, 907
- Nonfluent aphasia, progressive, 937
- Non-REM sleep, 639, 640, 641f
- Nonverbal auditory agnosia, 905
- Noradrenaline, 238f
- Norepinephrine, 20, 237, 237f, 238f, 268, 630, 636f, 636–637, 695  
 functions and locations of, 20t, 632t, 636, 637  
 receptors, 20t, 632t, 636  
 in sleep-wake cycle, 636–637, 640, 641f  
 in sympathetic nervous system, 23f
- Normal pressure hydrocephalus, 157–158, 208–209, 210f–211f, 939
- Nose, examination of, 9
- Notochord, 796f
- Nuchal rigidity in meningitis, 160, 160t
- Nuclear layers of retina, 462f
- Nuclear medicine, 100
- Nuclei, 21
- Nucleus, cellular, 18f
- Nucleus accumbens, 744, 755, 830  
 anterolateral view, 743f  
 in coronal section, 748f, 779f, 828f  
 and dopaminergic projection systems, 636f  
 lateral view, 743f  
 MRI image, 115f, 117f
- Nucleus ambiguus, 502f, 503f, 504, 504t, 505, 624  
 in axial section, 655f  
 and glossopharyngeal nerve, 532, 533f, 563  
 in myelin-stained section, 622f  
 and vagus nerve, 534, 535f
- Nucleus basalis, 634, 634f, 830  
 in coronal section, 748f, 829f  
 MRI image, 115f
- Nucleus cuneatus. *See* Cuneate nucleus
- Nucleus dorsalis of Clark, 226f, 711, 712f
- Nucleus gracilis. *See* Gracile nucleus
- Nucleus linearis, 637f
- Nucleus of diagonal band of Broca, 634, 634f, 829f, 830
- Nucleus proprius, 225f
- Nucleus pulposus, 319, 320f
- Nucleus raphe. *See* Raphe nucleus
- Nucleus solitarius, 502f, 503f, 504t, 505, 516f, 626  
 in axial section, 655f  
 in breathing control, 648  
 in cardiovascular control, 649  
 caudal, 504t, 505, 532, 533f, 535, 563, 626, 649  
 in myelin-stained section, 622f
- rostral, 504t, 505, 517f, 518, 532, 533f, 535, 563, 626  
 and vagus nerve, 535f
- Number recognition, 922f
- Nylén-Bárány positional testing, 530
- Nystagmus, 60, 76, 530, 530t, 587, 610  
 in cerebellar lesions, 719  
 optokinetic, 60, 76, 592–593, 610, 918t, 920  
 in Parinaud's syndrome, 590  
 slow and fast phases in, 60, 593, 610
- O**
- Obex, 39f, 498f, 499
- Oblique muscles of eye, 569f  
 inferior, 568, 569f, 570, 570t, 572f, 572t, 609  
 superior, 542f, 568, 569f, 570, 570t, 609
- Ob receptors, 801
- Observation of patient, 64
- Obsessive-compulsive disorder, 863
- Obtundation, 643t, 645–646
- Obturator externus muscle, 324t
- Obturator nerve  
 functions of, 324t, 361, 361t, 385  
 and lumbosacral plexus, 357, 357f, 358f  
 neuropathy of, 361t, 365  
 and regions of sensory innervation, 359f
- Occipital bone, 127f, 128f, 496f, 701f
- Occipital cortex, 487, 491f, 732f, 736f
- Occipital gyrus, 26f
- Occipital horn of lateral ventricle, 135f, 136, 136t  
 CT image, 105f, 177f, 179f, 210f  
 MRI axial image, 110f, 199f, 200f, 202f, 421f, 731f  
 MRI sagittal image, 117f  
 in sagittal section, 837f
- Occipital lobe, 24, 24f, 25, 26f, 43  
 blood supply of, 397f, 653f  
 and cerebral arteries, 393f  
 corticopontine fibers from, 619f  
 CT image, 104f, 105f, 443f, 682f, 691f, 975f  
 infarction of, 687, 691f, 967–968, 970f  
 MRI axial diffusion-weighted image, 673f, 688f, 725f  
 MRI axial T1-weighted image, 109f–111f, 484f, 611f, 868f  
 MRI axial T2-weighted image, 421f, 429f, 607f, 679f, 680f, 681f, 689f, 725f, 969f  
 MRI parasagittal image, 422f  
 MRI sagittal image, 116f, 117f, 308f, 976f  
 primary visual cortex in, 28, 28f  
 seizures in disorders of, 854t
- Occipital neuralgia, 335
- Occipital pole, 26f, 27f, 726f
- Occipital sinus, 410f
- Occipital somites, 504
- Occipitotemporal cortex, 468, 468f  
 inferior. *See* Inferior occipitotemporal cortex

- Occipitotemporal gyrus, 25, 27f, 832f
- Occipitotemporal sulcus, 25, 27f
- Ocular apraxia, 925
- Ocular dominance columns, 468–470, 469f, 471f, 492
- Ocular myasthenia, 327
- Oculocephalic testing, 60, 62, 76, 593
- Oculomotor channel, 754, 754f, 754t, 790
- Oculomotor nerve (CN III), 131f, 238f, 508–509, 509f, 562, 609 and brainstem, 38f, 39f, 651f, 652 and cavernous sinus, 571, 571f, 585, 585f, 586 and circle of Willis, 392f compression in uncus herniation, 145 exit foramen, 500, 501f, 502t in extraocular movements, 60, 76, 568, 570t, 570–571 fascicles of, 570, 571, 571f, 619f, 654f, 749f functional category, 506t, 508 functions of, 23f, 40t, 497t function testing of, 59–60 in horizontal eye movements, 587, 587f, 588f inferior division of, 570, 576 in situ view, 571f, 573f and intracranial aneurysm sites, 152, 152f MRI image, 116f palsy of, 152, 574–576, 582, 593–595, 596f in pathological specimen, 188f peripheral and parasympathetic ganglia, 507t in pupillary responses, 59–60, 76, 579f, 582 superior division of, 570, 576 surface anatomy of, 498f, 499f, 500
- Oculomotor nuclei, 503f, 504, 570–571, 572f, 609, 617, 624 in axial section, 654f functions of, 504t, 572t in horizontal eye movements, 587, 587f, 588, 588f in situ view, 571f in myelin-stained section, 619f in oculomotor nuclear complex, 572f and vestibular nuclei, 526f
- Oculomotor palsy, 152, 574–576 diplopia in, 575, 593–595, 596f pupils in, 576, 582
- Odontoid, 337f
- Off-center cells, 462, 463, 463f, 465, 469, 470f
- Olfaction, 507–508, 824–825, 825t, 831–833, 832f, 881 amygdala in, 833, 851, 852 assessment of, 58, 508 in frontal lobe disorders, 918t, 920 loss of, 508 and memory, 833, 851 in seizures, 855
- Olfactory area, 827
- Olfactory bulbs, 27f, 500, 507, 826f, 832, 832f, 833, 850f, 881 MRI image, 542f, 869f and skull foramina, 501f
- Olfactory cortex, 824t, 824–825, 825t, 832 orbitofrontal, 881 primary, 832f, 833, 881 and thalamus, 284f
- Olfactory mucosa, 831, 832f
- Olfactory nerve (CN I), 507t, 507–508, 562, 832, 832f, 881 exit foramen, 500, 501f, 502t functional category, 506t, 507 functions of, 40t, 497t function testing of, 58 surface anatomy of, 500
- Olfactory nucleus, anterior, 748f, 828f, 832, 832f
- Olfactory receptor neurons, 831, 832, 832f
- Olfactory stria lateral, 748f, 828f, 831t, 832f, 833 medial, 831t, 832f, 833
- Olfactory sulcus, 25, 27f, 500, 826f, 832 CT image, 103f MRI image, 110f, 484f, 542f, 827f
- Olfactory system, 831–833, 832f
- Olfactory tract, 27f, 500, 507, 826f, 832, 832f
- Olfactory tubercle, 830, 833
- Oligoclonal bands in multiple sclerosis, 169, 251
- Oligodendrocytes, 18f, 19
- Oligodendroglioma, 158, 158t
- Olivary nuclear complex, superior, 523f, 524, 524f, 621f, 625
- Olivary nucleus dorsal accessory, 622f inferior, 499, 622f, 708f, 713 medial accessory, 622f
- Olive, 38f, 108f, 498f, 499f
- Olivocerebellar fibers, 708f, 713
- Olivopontocerebellar atrophy, 768
- Omega area, 112f, 259, 260f, 297, 299f
- On-center cells, 462, 463, 463f, 465, 469, 470f
- One-and-a-half syndrome, 588f, 589
- On/off cells, 465
- On-off phenomena in Parkinson's disease, 767, 779–780
- Onuf's nucleus, 292f, 293t, 294, 295
- Operculum frontal. *See* Frontal operculum parietal, 25, 42f, 111f, 826f
- Ophthalmic artery, 118f, 391f, 392, 442f, 476
- Ophthalmic division of trigeminal nerve, 500, 501f, 510, 510f, 511, 513f, 562 and cavernous sinus, 585, 585f, 586
- Ophthalmic veins, 410f
- Ophthalmoplegia, internuclear, 588f, 589, 605–606
- Ophthalmoscopic exam, 58, 76, 470, 476
- Opiate medications, 280
- Opiate peptides, endogenous, 280
- Opponens digiti minimi muscle, 324t
- Opponens pollicis muscle, 323t, 360, 363
- Opsoclonus, 720
- Optic ataxia, 925
- Optic canal, 500, 501f, 502t, 508
- Optic chiasm, 26f, 38f, 59, 463, 474f, 579f blood supply of, 476 in coronal section, 748f, 786f, 799f, 829f embryonic development of, 796f inferior view, 797f and medial hypothalamic nuclei, 798f medial view, 797f MRI axial image, 110f, 421f, 484f, 954f MRI coronal image, 115f, 482f, 778f MRI sagittal image, 116f, 482f, 693f and pituitary hormones, 802f surface anatomy of, 498f vision loss in compression of, 473, 481, 482f
- Optic disc, 143, 460, 460f, 477
- Optic nerve (CN II), 460, 460f, 463, 463n, 474f, 507t, 508, 562, 571f blood supply to, 476 and brainstem, 38f, 39f and cavernous sinus, 585, 585f in coronal section, 748f, 828f CT image, 103f exit foramen, 500, 501f, 502t functional category, 506t, 508 functions of, 40t, 497t function testing of, 58–60, 76 inferior view, 797f intracranial pressure increase affecting, 143 ischemic neuropathy of, 476 MRI axial image, 110f, 421f, 484f, 546f, 868f, 954f MRI coronal image, 542f, 543f in multiple sclerosis, 251 neuritis of, 59, 251, 477–478, 479–480 ophthalmoscopic exam of, 58, 76 in pupillary responses, 59–60, 76, 579f surface anatomy of, 26f, 498f, 499f, 500 vision loss in lesions of, 473
- Optic neuritis, 59, 251, 477–478, 479–480
- Optic radiations, 231f, 390, 390f, 465f, 465–466, 474f, 579f blood supply of, 477 CT image, 431f, 491f, 965f MRI image, 421f, 954f
- Optic tract, 38f, 463, 464f, 474f, 508 blood supply of, 476 in coronal section, 749f, 786f, 799f, 829f CT image, 104f inferior view, 797f MRI axial image, 110f, 421f, 484f, 954f MRI coronal image, 115f, 602f, 817f, 818f MRI sagittal image, 116f in myelin-stained section, 619f and pupillary constriction, 579f surface anatomy of, 498f, 499f and thalamus, 284f
- Optokinetic nystagmus, 60, 76, 592–593, 610 in frontal lobe disorders, 918t, 920
- Oral phase of swallowing, 539
- “Orator's hand” in median nerve palsy, 363, 363f
- Orbicularis oculi muscle, 585
- Orbital apex, 585–586 syndrome of, 167, 586
- Orbital fat, 542f
- Orbital fissure, superior, 500, 501f, 502t, 509, 609 and trigeminal nerve, 510f, 511, 562
- Orbital frontal cortex contusion of, 177f medial, 636f, 755f, 869f, 881 olfactory area in, 832f, 833, 881, 915f ventromedial lesions of, 917
- Orbital frontal gyrus, 25, 27f CT image, 103f and limbic system, 42f, 826f medial, 755, 825 MRI image, 110f, 827f
- Orbital gyrus, 26f
- Orbitalis muscle, 581
- Orbital plate of frontal bone, 127f
- Orbital pseudotumor, 597–598, 601f
- Order, frontal lobe functions in, 914t, 916, 978
- Orexin, 630, 632t, 638 in sleep–wake cycle, 640, 641f, 642, 800, 801
- Organ of Corti, 523
- Organum vasculosum, 138, 138f
- Orientation, anatomical, terms describing, 16f, 16–17
- Orientation, and mental status, 53–54, 889, 913
- Orientation columns, 469f, 470, 471f
- Orthopedic gait disorder, 250t
- Orthostatic measurement of blood pressure, 529
- Ossicles of middle ear, 521
- Osteophytes, spinal, 329t, 330
- Otic ganglion, 507t, 509f, 532, 533f
- Otoacoustic emissions, 521, 523
- Otoconia, 531
- Otoliths, 522f, 526, 531
- Otorrhea, CSF, 75t
- Outer hair cells, 521, 522f
- Oval window, 521, 522f
- Ovarian cancer, 160
- Overflow incontinence, 294f, 295
- Overshoot in ataxic movements, 68, 69, 719
- Oxytocin, 796, 801, 803, 819, 820 deficiency of, 808 functions of, 803f, 804

## P

### Pain

- anterolateral pathway in, 34, 35, 36f, 274, 274t, 278, 278f, 279, 311
- assessment of sensation, 71 in back, 328–329
- central modulation of, 280, 280f
- complex regional pain syndromes, 326

- facial grimace response to, 77  
 in gait, 250t  
 gate control theory of, 280  
 in headache, 139–141  
 loss of sensation, 289  
 neuralgic, 141  
 radicular, 286, 330  
 sensory neuron fiber types in, 277t  
 withdrawal from, in coma exam, 77
- Palate  
 elevation of, 62, 539  
 soft, 535f  
 tremor of, 764
- Paleocortex, 827, 828t
- Palinopsia, 44, 924
- Pallidotomy in Parkinson's disease, 781, 783f
- Pallidum, ventral, 748f, 755, 829f, 830
- Palmar interosseous muscles, 324t, 360t, 361
- Palmaris longus muscle, 323t
- Palmomental reflex, 68
- Palpation of muscles, 64
- Palsy, 240t  
 abducens, 143–144, 577–578, 578f, 595  
 Erb–Duchenne, 362, 369  
 facial, 244, 245, 518–520, 545–546  
 median, 363, 363f  
 oculomotor, 152, 574–576, 582, 593–595, 596f  
 progressive supranuclear, 589, 768  
 pseudobulbar, 539  
 trochlear, 576f, 576–577, 596–597
- Pancoast's syndrome, 362
- Pancreas, 238f
- Panencephalitis, subacute sclerosing, 164
- Panhypopituitarism, 808–809, 813–815, 817f
- Papez, James, 841
- Papez circuit, 836f, 841
- Papilledema, 143, 144f
- Papillitis, 477
- Parabigeminal nucleus, 619f
- Parabrachial nucleus, 620f, 633
- Paracentral lobule, 25, 26f  
 CT image, 106f, 107f, 420f  
 MRI image, 112f, 113f, 116f
- Paracusis, 926
- Parafascicular nuclei, 750, 751
- Parahippocampal cortex, 832f, 837, 838f, 882
- Parahippocampal gyrus, 25, 27f, 837, 881  
 components of, 837, 837t  
 in coronal section, 835f  
 and dopaminergic projection systems, 636f  
 embryonic development of, 834f  
 in limbic system, 42f, 824t, 825, 826f  
 medial view, 836f  
 in memory, 834  
 MRI image, 114f, 117f, 827f, 872f, 879f  
 and olfactory structures, 832f
- Paralimbic cortex, 824. *See also* Limbic cortex
- Parallel fibers, 705, 705f, 706f, 707
- Paralysis, 240t  
 flaccid, 64  
 generalized, 247  
 patterns and localization of, 240–247  
 psychogenic, 80
- Paramagnetic substances affecting MRI, 95
- Paramedian arteries, 651f, 652, 652f, 654f, 695
- Paramedian pontine reticular formation, 621f  
 in horizontal eye movements, 587f, 588, 588f, 589, 610
- Paramnesia, reduplicative, 913
- Paraneoplastic syndromes, 159–160
- Paranoid behavior in Wernicke's aphasia, 899
- Paraparesis, 245f, 245–246
- Paraphasic errors in speech, 54, 899
- Paraplegia, 245–246
- Parasagittal section, 17
- Parasitic infections, 160, 165–166  
 brain abscess in, 162  
 cysticercosis, 166, 200, 201f–203f, 972–973, 976f  
 toxoplasmosis, 162, 165–166, 773–774, 776f
- Parasol cells, 462–463, 468f, 492
- Parasubiculum, 835f
- Parasympathetic column, 503f
- Parasympathetic functional category, 506f, 508  
 facial nerve in, 515–516  
 glossopharyngeal nerve in, 532  
 vagus nerve in, 534
- Parasympathetic ganglia, 23f, 236, 238f, 507t, 562
- Parasympathetic nervous system, 15t, 23f, 24, 236–237, 238f, 268  
 in bladder function, 293t  
 in bowel function, 293t, 295  
 cranial nerves in, 236f, 503f, 504t, 504–505, 506t, 507t, 509, 509f, 562  
 efferents in, 237f  
 functions of, 23f, 24, 236  
 neurotransmitters in, 237  
 in pupillary constriction, 578–580, 579f, 609  
 in sexual function, 293t, 295
- Parasympathetic nuclei, 236f, 504t, 504–505, 506t, 624–625  
 sacral, 236f, 237f, 292f, 293t, 294
- Paraterminal gyrus, 26f, 115f, 116f, 826f
- Paratonia, 80, 759, 920
- Paraventricular nucleus, 798f, 799, 799f, 801, 803, 819  
 magnocellular portion, 802f, 820
- Paravertebral ganglia, 236, 237f, 238f
- Paravertebral sympathetic chain, 580, 581f
- Paresis, 240t  
 gait in, 250t  
 in syphilis, 163
- Paresthesias, 286
- Parietal association cortex, 223f, 890f, 907, 929–930, 943f
- Parietal lobe, 24, 24f, 25, 43–44  
 and cerebral arteries, 393f  
 and cortical functional areas, 390f  
 corticopontine fibers from, 619f  
 CT image, axial, 185f, 420f, 431f, 444f, 451f, 957f, 965f, 970f  
 CT image, in subdural hematoma, 172f  
 CT image, with and without contrast, 451f  
 CT image, with horizontal slices, 256f  
 in hemineglect, 908, 978  
 hemorrhage in, 449–450, 451f  
 infarction of, 296–297, 298f  
 language functions of, 895  
 and motor cortical areas, 28, 28f, 222  
 MRI axial image, 111f, 112f, 429f  
 MRI coronal image, 114f, 976f  
 MRI sagittal image, 116f, 117f, 976f  
 optic radiations in, 465f, 477  
 seizures in disorders of, 854t  
 in spatial analysis, 907
- Parietal lobules  
 anterior inferior, 928f  
 inferior. *See* Inferior parietal lobule  
 posterior inferior, 928f  
 superior. *See* Superior parietal lobule
- Parietal operculum, 25, 42f, 111f, 826f
- Parieto-occipital cortex, 468, 468f  
 blood supply of, 477  
 dorsolateral, 468f, 477, 924–925  
 and thalamus connections, 285f
- Parieto-occipital fissure, 467f  
 MRI image, 116f, 422f, 482f, 693f
- Parieto-occipital sulcus, 24, 24f, 26f, 466f
- Parieto-occipito-temporal cortex, 591, 591f
- Parinaud's syndrome, 157, 584, 589, 590  
 in hydrocephalus, 157, 590  
 light–near dissociation in, 584, 590  
 in pineal region tumors, 159, 590, 606–607, 611f  
 setting-sun sign in, 157, 590
- Parkinsonism, 34, 765, 767–769  
 anticholinergic agents in, 753  
 atypical, 768, 781–784, 786f–787f  
 differential diagnosis of, 768t  
 gait in, 249t, 765, 766  
 pathologic changes in, 784, 786f–787f  
 signs in, 765  
 striatonigral degeneration in, 784, 786f–787f  
 vascular, 769
- Parkinson's disease, 636, 742, 765–767, 777–781, 782f–783f  
 deep brain stimulation in, 772, 780–781, 782f  
 dopamine in, 753, 765, 767  
 gait in, 249t, 765, 766  
 MRI-guided focused ultrasound in, 781, 783f  
 Myerson's sign in, 68, 766, 920–921  
 on–off phenomenon in, 767, 779–780
- SPECT imaging in, 101, 765f, 766  
 substantia nigra in, 747, 753, 765, 765f  
 surgical treatments for, 767  
 tremor in, 753, 763, 765, 766
- Parotid gland, 509f, 532, 533f
- Pars compacta, 635f, 635–636, 747, 750, 750f, 752f, 765, 789
- Parsonage–Turner syndrome, 362–363
- Pars opercularis, 26f
- Pars orbitalis, 26f
- Pars reticulata, 284f, 747, 750, 750f, 751, 751f, 789
- Pars triangularis, 26f
- Parvocellular layer of lateral geniculate nucleus, 462, 464, 465f, 467, 468f, 492
- Parvocellular red nucleus, 619f, 708f, 709
- Past pointing in ataxia, 68
- Patellar tendon reflex, 67t, 333t
- Patent foramen ovale, 403, 407
- Pathophysiology, 101
- Pectineus muscle, 324t
- Pectoralis muscles, 323t
- Pectoral nerves, 323t, 356f, 357f
- Pedicle  
 of flocculonodular lobe, 702f  
 vertebral, 319, 320f
- Pedunculopontine tegmental nucleus, 619f, 634, 634f
- Pellagra, 939
- Pelvic examination, 10
- Pelvic floor muscles, 292f, 293t, 294, 295
- Pen-and-paper tests in neglect, 910–912, 912f
- Penetrating trauma of head, 147
- Penis, erectile and ejaculatory function of, 238f, 293t, 295
- Penumbra, 406, 440f
- Peptide neurotransmitters, 19, 20t
- Perforant pathway, 831t, 835f, 838, 838f, 882
- Perforated substance, anterior, 27f, 826f, 832f, 833
- Periamygdaloid cortex, 748f, 881  
 in coronal section, 828f  
 in olfactory system, 832f, 833, 837
- Periaqueductal gray  
 and anterolateral somatosensory pathways, 276f, 279  
 in situ view, 571f, 573f  
 in myelin-stained section, 619f, 620f  
 in pain modulation, 280, 280f, 650
- Pericallosal artery, 118f, 120f, 393, 393f, 418f
- Pericranium, 126f, 320f
- Periglomerular cells, 833
- Perilymph, 521, 522f
- Perimesencephalic hemorrhage, 149, 417f
- Perineal nerve, 359f
- Periosteal layer of dura, 126f, 130
- Periosteum, 126f, 320f
- Peripheral nerves, 22f  
 disorders of, 243, 244, 246, 247, 290, 325–327

- Peripheral nervous system, 14, 22–24, 355–385  
 autonomic. *See* Autonomic nervous system  
 components of, 14f, 15t  
 cranial nerves in. *See* Cranial nerves  
 nerves  
 disorders of, 325–328  
 neurotransmitters in, 19–20, 20t, 237  
 spinal nerves in. *See* Spinal nerves
- Perirhinal cortex, 832f, 835f, 837, 838f, 882
- Perivascular space, 126f, 131
- Periventricular area of  
 hypothalamus, 819, 829f
- Periventricular nucleus, 798, 799f, 801, 819
- Peroneal nerve, 325t  
 deep. *See* Deep fibular nerve  
 functions of, 361, 361t  
 and lumbosacral plexus, 357, 357f, 358f  
 neuropathy of, 361t, 365, 377, 377f  
 region of sensory innervation, 359f, 377f  
 superficial. *See* Superficial fibular nerve
- Peroneus muscles, 325t
- Perseveration, 44, 918, 965, 969f
- Persistent vegetative state, 645
- Personality changes in frontal lobe disorders, 44, 917
- Pes hippocampus, 117f, 835, 836f, 837f
- Petechial hemorrhage, 147
- Petit mal seizures, 857
- Petrosal ganglion, 532
- Petrosal nerve  
 greater, 509f, 515, 516f, 521f  
 lesser, 509f, 532, 533f
- Petrosal sinus  
 inferior, 133f, 409, 811f  
 sampling of, 806, 810, 811f  
 superior, 133f, 409, 410f
- Petrotympenic fissure, 501f, 516, 516f
- Petrous segment of internal carotid artery, 118f, 120f, 391f, 392
- Petrous temporal bone, 127f, 129f, 501f, 521f  
 auditory canal in, 515, 520–521  
 CT image, 103f, 128f, 210f, 729f  
 MRI image, 553f, 559f, 602f, 731f
- Phalen's sign, 363–364
- Pharyngeal nerve, 535f
- Pharynx, 482f, 539, 540
- Phonophobia in meningitis, 160, 160t
- Phoria, 574
- Phosphenes, 472t
- Photopsias, 472t
- Photoreceptors, 460, 461–462, 462f, 492
- Photosensitivity, 139, 140, 160, 160t
- Phrenic nerve, 323t, 357, 384, 648, 649f
- Physical examination, 4–10, 50, 51t, 74  
 in coma, 74  
 in head trauma, 74, 75t, 147  
 in motor exam, 64–65
- Physiological tremor, 763–764
- Pia, 16, 126f, 129, 131  
 of cerebellum, 704f  
 and circulation of CSF, 134f  
 CT image, 178f  
 of spinal cord, 132, 319, 320f
- Pick bodies, 937
- "Pie in the sky" visual field defect, 465, 474, 474f
- "Pie on the floor" visual field defect, 465, 474, 474f
- Pigment epithelium, 462f
- Pill-rolling tremor, 763, 766
- Piloerection, 238f
- Pineal gland, 26f, 39f  
 calcification of, 104f, 142, 177f, 179f, 210f, 691f, 959f  
 and circumventricular organs, 138, 138f  
 CT image, 104f, 177f, 179f, 210f, 691f, 959f  
 MRI image, 110f, 114f, 116f  
 surface anatomy of, 498f  
 tumors of, 159, 195–200, 590, 606–607, 611f
- Pinealomas, 159
- Pineal recess, 135f
- Piriform cortex, 748f, 850f, 881  
 in coronal section, 828f  
 in olfactory system, 832f, 833, 837
- Pituitary apoplexy, 586, 598–600, 602f, 808–809
- Pituitary fossa, 103f, 496f, 602f, 797
- Pituitary gland, 794–820  
 adenoma of, 158, 159, 804–807, 809–812  
 anatomical relations of, 796, 797f  
 anterior. *See* Anterior pituitary and cavernous sinus, 585f  
 and cerebral venous drainage, 410f  
 and dural venous sinuses, 133f  
 embryonic development of, 796, 796f  
 hormones of, 801–804, 808–809  
 incidentalomas of, 807  
 intermediate lobe of, 796, 796f  
 MRI axial image, 109f, 547f, 602f  
 MRI coronal image, 115f, 482f, 817f  
 MRI sagittal image, 116f, 693f  
 and oculomotor nerve, 571f  
 in panhypopituitarism, 808–809, 813–815, 817f  
 posterior. *See* Posterior pituitary
- Pituitary stalk, 796f, 797, 797f  
 MRI image, 110f, 115f, 602f, 817f
- Planes, 17, 17f, 86
- Plan on proposed interventions, 7
- Plantaris muscle, 324t
- Plantar nerves, 359f
- Plantar response, 67, 67f  
 silent, 248
- Plasmapheresis, 327, 328
- Plasticity, synaptic, 839
- Plastic rigidity, 759
- Plegia, 240t
- Plexiform layers of retina, 462f
- Pneumonia, aspiration, 539
- Polymorphic layer  
 of dentate gyrus, 834, 835f  
 of hippocampus and subiculum, 835, 835f
- Polymyositis, 328
- Polyneuropathy, 326  
 acute inflammatory  
 demyelinating, 326–327, 381–382  
 distal symmetrical, 289f, 290, 326
- Polyopia, 924
- Polyradiculopathy,  
 cytomegalovirus, 332
- Pons, 15, 15f  
 ataxia in lesions of, 717  
 in axial section, 517f, 620f–621f  
 blood supply of, 652–653, 653f–655f, 657, 660t, 661–662  
 as brainstem structure, 38f, 39f, 41f, 497, 561, 617, 618–621, 620f–621f  
 caudal, 655f  
 CT image, 103f, 210f, 420f, 682f, 729f, 970f  
 and descending motor pathways, 234f, 235f, 236f  
 hemorrhage in, 154, 663  
 infarction of. *See* Pontine infarction  
 and lateral corticospinal tract, 234f  
 lateral view, 701f  
 meningioma compressing, 557–558, 560f–561f  
 micturition center in, 292f, 294, 650  
 midsagittal view, 496f  
 and motor system organization, 228f  
 MRI axial FLAIR image, 873f  
 MRI axial proton density-weighted image, 547f, 608f  
 MRI axial T1-weighted image, 109f, 553f, 560f, 561f, 601f, 732f, 736f  
 MRI axial T2-weighted image, 602f, 674f, 681f, 725f, 827f  
 MRI coronal image, 114f, 264f, 559f, 776f, 868f  
 MRI diffusion-weighted image, 669f  
 MRI normal image, 736f, 737f  
 MRI sagittal T1-weighted image, 116f, 199f, 308f, 560f, 611f, 693f, 737f  
 MRI sagittal T2-weighted image, 312f  
 in myelin-stained section, 620f–621f  
 in pain modulation, 280f  
 pupils in lesions of, 583  
 reticular formation in. *See* Pontine reticular formation  
 rostral. *See* Rostral pons  
 sagittal view in situ, 701f  
 and serotonergic projection systems, 637f  
 and somatosensory system, 275f, 276f, 288f, 289, 289f  
 surface anatomy of, 26f, 498f, 499, 499f  
 and trigeminal sensory system, 512f  
 vascular syndromes of, 660t, 661–662  
 in vertebrobasilar ischemia, 657  
 and visual pathways, 464f
- and weakness patterns, 241f, 242f, 243f, 244f, 245f, 246f, 262–263, 267f  
 wrong-way eyes in lesions of, 592, 604, 607f, 660t
- Pontine arteries, 653, 692f
- Pontine cistern, 136, 137, 137f
- Pontine infarction, 627, 660t, 661–662  
 dysarthria–hemiparesis in, 262–263, 267f, 660t, 661, 670, 673f  
 locked-in syndrome in, 675–676, 679f–680f  
 wrong-way eyes in, 604, 607f, 660t
- Pontine nuclei, 619f, 620f, 621f, 628, 655f, 703f  
 and cerebellar input pathways, 711
- Pontine reticular formation, 631f, 695  
 in axial section, 654f  
 and descending motor pathways, 236f  
 in myelin-stained section, 620f, 621f  
 paramedian, 587f, 588, 610, 621f
- Pontine reticulospinal tract, 236f, 279f
- Pontine tegmentum, 588, 621  
 lesions of, 661, 925–926  
 nuclei in, 624
- Pontocerebellar fibers, 619f, 620f, 621f, 703f, 710t, 711
- Pontomedullary junction, 15f, 496f, 497, 726f
- Pontomedullary reticular formation, 751
- Pontomesencephalic junction, 15f, 496f, 497
- Pontomesencephalic reticular formation, 41f, 630–631, 631f, 633
- Popliteus muscle, 324t
- Pork tapeworm, 166
- Positron emission tomography, 100–101, 876, 881f
- Postcentral gyrus, 25, 26f, 27f, 28  
 CT image, 106f, 107f, 172f, 256f–257f, 444f  
 infarction of, 296–297, 298f–299f  
 MRI axial image, 112f, 113f, 258f–259f, 298f–299f, 448f  
 MRI sagittal image, 116f, 117f  
 primary somatosensory cortex in, 222  
 and taste pathways, 517f  
 three-D surface reconstruction, 97f
- Postcentral sulcus, 26f
- Postcommissural fornix, 836f, 840f, 841, 882
- Postconcussive syndrome, 147
- Posterior, 16f, 16–17
- Posterior approach in spinal surgery, 333
- Posterior auricular branch of facial nerve, 516f
- Posterior cerebellar artery, 114f
- Posterior cerebral artery, 45f, 46, 131f, 391, 391f, 392, 393f, 397f, 453  
 angiography of, 118f, 119f, 683f  
 in axial section, 654f

- and brainstem blood supply, 650, 651f, 652, 653f  
 calcarine branch, 119f  
 and circle of Willis, 392f  
 clinical syndromes of, 399t, 400  
 CT image, 89f, 178f, 443f, 487, 491f  
 deep territory, 397f, 453  
 embolic occlusion of, 486–487  
 infarction of. *See* Posterior cerebral artery infarction  
 MRA image, 120f  
 MRI axial image, 421f, 681f, 689f  
 MRI coronal image, 96f, 559f, 726f  
 MRI parasagittal image, 422f  
 and oculomotor nerve, 571f, 575  
 in pathologic specimen, 189f  
 segments and branches of, 392  
 vascular territory of, 394, 394f, 401f, 443f, 453, 477  
 in vertebrobasilar system, 650, 652  
 watershed zones, 400–401, 401f, 477, 901
- Posterior cerebral artery infarction, 399t, 400  
 CT image, 487, 491f  
 homonymous hemianopia in, 399t, 400, 414–416, 486–487  
 in MCA–PCA watershed, 400–401, 901  
 MRI image, 416, 421f–422f  
 primary visual cortex damage in, 475  
 territory and deficits in, 399t
- Posterior choroidal artery, 119f, 396f
- Posterior cingulate cortex, 928f, 943f
- Posterior circulation, 45f, 46, 391, 391f, 453  
 angiography of, 119f  
 disorders of, 656–663
- Posterior clinoid process, 127f, 501f, 521f, 797  
 CT image, 420f  
 midsagittal view, 496f
- Posterior column nuclei, 498f, 499, 511t
- Posterior column of spinal cord, 22f, 39f, 225, 225f, 226f, 277, 318f  
 surface anatomy of, 498f, 499, 499f
- Posterior column somatosensory pathway, 34–35, 35f, 274, 275f, 277–278, 311, 694  
 functions of, 274t  
 nuclei in, 35f, 275f, 277, 626  
 somatotopic organization of, 277–278, 278f
- Posterior commissure, 17, 496f, 579, 579f
- Posterior communicating artery, 45f, 391, 392  
 aneurysm of, 149, 152, 152f, 412–413, 419f, 575, 576, 593–595, 596f  
 angiography of, 118f, 119f, 594–595, 596f  
 and circle of Willis, 392f  
 MRA appearance, 120f  
 and oculomotor nerve, 571, 571f, 575, 576, 593–595, 596f, 609  
 in vertebrobasilar system, 650
- Posterior cord of brachial plexus, 356f, 357
- Posterior cord syndrome, 291f, 292
- Posterior cortical atrophy, 937–938
- Posterior cranial fossa, 127f, 128–129, 130, 521f  
 blood supply to, 650  
 cerebellum in, 700, 701f  
 contents of, 129, 129f  
 CT image, 128f
- Posterior division of brachial plexus, 356f
- Posterior femoral cutaneous nerve, 357f, 358f
- Posterior horn of lateral ventricle. *See* Occipital horn of lateral ventricle
- Posterior horn of spinal cord, 17, 22f, 224, 225f, 225t, 318f, 511t  
 in pain modulation, 280f
- Posterior hypothalamic nucleus, 798f, 799, 799f, 819
- Posterior hypothalamic region, 798f, 799, 799f, 801, 819
- Posterior inferior cerebellar artery, 45f, 46, 227f, 713–714, 714f  
 aneurysm of, 152f  
 angiography of, 119f, 683f, 692f  
 in axial section, 655f  
 and brainstem blood supply, 650, 651f, 652, 653f, 655f  
 and circle of Willis, 392f  
 infarction of, 715, 723, 726f  
 lateral view, 701f  
 MRA image, 120f  
 MRI axial image, 726f  
 territory of, 714f  
 in vertebrobasilar system, 650, 652
- Posterior inferior parietal lobule, 928f
- Posterior interosseous nerve, 323t, 372
- Posterior limb of internal capsule, 232f, 233  
 and basal ganglia, 744  
 blood supply of, 396f, 397f  
 in coronal section, 749f, 786f  
 and corticospinal tract, 33f, 231f  
 CT image, 104f, 431f, 432f, 959f, 968f  
 in horizontal section, 745f  
 and lateral corticospinal tract, 233, 234f, 267  
 lateral view, 746f  
 MRI image, 111f, 264f, 302f, 429f, 783f  
 and posterior column somatosensory pathway, 278
- Posterior lobe of cerebellum, 700, 701f, 702f, 711f
- Posterior longitudinal ligament, 320, 320f
- Posterior pituitary, 138, 138f, 796, 820  
 embryonic development of, 796, 796f  
 hormones of, 802f, 803, 803f, 820  
 medial view, 797f
- Posterior spinal artery, 46, 227, 227f, 228, 267
- Posterior thalamic peduncle, 231f
- Posterior tibial nerve, 361t
- Posterolateral disc herniation, 320, 321f
- Posterolateral fissure, 701, 702f
- Postganglionic lesions, 583
- Postganglionic neurons, 236, 237, 237f
- Post-ictal, definition of, 852
- Postsynaptic cells, 18f, 19
- Posttraumatic headache, 140
- Postural instability in Parkinson's disease, 765, 766
- Postural tremor, 719, 762, 763t, 763–764
- Posturing, 68, 650  
 in brain death, 79  
 in coma, 77–78, 78f
- Post-void residual volume of urine, 294
- P pathway, 464
- “Preacher's hand” in median neuropathy, 363, 363f
- Pre-Bötzinger complex, 648, 649f
- Precentral gyrus, 25, 26f, 27f, 28  
 and corticospinal tract, 33f  
 CT image, 106f, 107f, 172f, 256f–257f, 431f, 444f  
 face area of, 255–259, 260f  
 hand area of, 253–254, 256f–257f  
 infarction of, 253–259, 256f–260f  
 and lateral corticospinal tract, 230, 230f, 267  
 leg area of, 254–255, 258f–259f  
 MRI axial image, 112f, 113f, 258f–259f, 298f–299f, 448f  
 MRI sagittal image, 116f, 117f  
 primary motor cortex in, 222, 230f  
 3D surface reconstruction, 97f
- Precentral sulcus, 26f, 27f
- Precession of protons in MRI, 90, 91f
- Precommissural fornix, 836f, 840f, 841, 882
- Precuneus, 25, 26f, 116f, 928f, 943f
- Prefrontal channel, 754, 754f, 754t, 790
- Prefrontal cortex, 755f, 915f, 915–916, 978  
 association, 30f, 43f, 890f  
 connections of, 915–916  
 and dopaminergic projection systems, 636f  
 gait in lesions of, 717  
 and language areas, 894f  
 in learning, 916  
 in memory, 916  
 and thalamus connections, 285f  
 ventral medial, 928f
- Preganglionic lesions, 583
- Preganglionic neurons, 236, 237, 237f
- Pregnancy, chorea in, 761
- Premotor cortex, 43f, 222, 223f, 755f, 915f  
 in disconnection syndromes, 905f  
 and language areas, 894f  
 and thalamus connections, 285f
- Preoccipital notch, 26f
- Preoptic area, 819, 830  
 in coronal section, 748f, 829f
- hypothalamic nuclei in, 798, 798f, 799f  
 ventral lateral, 639, 640, 641f, 800
- Preoptic nuclei, 798, 798f, 799f, 801, 819
- Prepontine cistern, 136, 137, 137f
- Prerubral field, 756f, 757
- Presenilin genes, 940
- Present illness, history of, 5–6
- Presubiculum, 835f
- Presynaptic cell, 18f
- Presynaptic terminal, 18f, 19
- Pretectal area  
 in attention, 930  
 MRI image, 611f  
 in vertical eye movements, 589  
 in visual pathway, 464, 464f, 579
- Pretectal nucleus, 579f
- Prevertebral ganglia, 236, 237f, 238f
- Primary auditory cortex, 28, 28f, 29, 43, 43f, 524f, 890f
- Primary fissure, 116f, 700, 702f
- Primary headache, 139t, 139–140
- Primary lateral sclerosis, 252
- Primary motor cortex, 28, 28f, 222, 223f, 755f, 889t, 890f  
 and association cortex, 43f  
 cell layers of, 30, 30f  
 and cerebral arteries, 393f  
 and cortical functional areas, 390f, 915f  
 corticospinal tract from, 32, 33f  
 in language, 895  
 and lateral corticospinal tract, 230, 230f
- Primary olfactory cortex, 832f, 833, 881
- Primary sensory neurons, 34, 35, 35f  
 in anterolateral pathways, 276f  
 in posterior column pathway, 275f  
 and trigeminal sensory system, 512f, 513
- Primary somatosensory cortex, 28, 28f, 222, 223f, 280, 311, 889t, 890f  
 and anterolateral pathway, 36f, 276f  
 and association cortex, 43f  
 and cerebral arteries, 393f  
 and cortical functional areas, 390f  
 patterns of sensory loss in lesions of, 288f, 288–289  
 and posterior column pathway, 35f, 275f, 278
- Primary visual cortex, 28, 28f, 466–470, 890f, 922  
 and association cortex, 43f  
 blood supply of, 477  
 cell layers of, 30, 30f, 466–467, 467f, 492  
 and cerebral arteries, 393f  
 columnar organization of, 468–470  
 and cortical functional areas, 390f  
 infarction of, 477, 486–487  
 MRI image, 484f  
 and optic radiations, 465f, 465–466

- pathways to, 464, 464f  
 retinotopic organization of, 466, 466f  
 syndromes of, 922  
 Priming of memory, 843f, 844  
 Primitive reflexes in frontal lobe lesions, 44, 68, 920  
 Prion-related illnesses, 167, 939  
 Progesterone, 803f  
 Progressive multifocal leukoencephalopathy, 165  
 Progressive supranuclear palsy, 589, 768  
 Projectile vomiting, 143  
 Prolactin, 801, 802t, 820  
   adenoma secretion of, 804, 805  
   deficiency of, 808  
   functions of, 803f, 804  
 Prolactin release-inhibiting factor, 803  
 Pronator drift, 248  
 Pronator quadratus muscle, 324t  
 Pronator teres muscle, 323t  
 Proprioception  
   assessment of, 71–72  
   and eye movements, 593  
   loss of, 289, 718  
   posterior column pathway in, 34, 35f, 274, 274t, 275f, 278f, 311  
   sensory neuron fiber types in, 277t  
   in spatial analysis, 907  
 Prosencephalon, 14–15, 15f, 796f  
 Prosody, 897  
 Prosopagnosia, 44, 923, 979  
 Protein, CSF, 161t, 168, 169, 327  
 Proverbs test of abstraction, 919, 919t  
 Pseudobulbar affect, 252, 539, 557–558, 560f–561f, 650  
 Pseudobulbar palsy, 539  
 Pseudocoma, 80, 646  
 Pseudodementia, 932, 935, 938  
 Pseudotumor cerebri, 141  
   orbital, 597–598, 601f  
 Psoas muscle, 324t  
 Psychiatric disorders, 862–864  
   attention impairment in, 932  
   auditory hallucinations in, 926  
   in Huntington's disease, 770, 771, 774–776  
   in Lewy body disease, 768  
   in multiple sclerosis, 251t  
   unresponsive state in, 646  
 Psychogenic symptoms, 79–81  
   amnesia in, 79, 849  
 Pterional craniotomy, 169–170  
 Pterygoid plexus, 410f  
 Pterygoid process, 102f  
 Pterygopalatine ganglion, 507t, 516  
 Ptosis of eyelid, 584–585  
   angiography in, 603f  
   in Horner's syndrome, 140, 582, 585, 600–601, 603f  
   in myasthenia gravis, 327, 379–381, 585  
 Pudendal nerve, 357, 357f, 358f, 359f, 384  
 Pulse, 10  
 Pulvinar, 281f, 282t  
   in attention, 930  
   inputs to, 282t, 284  
   MRI image, 110f  
   in visual pathway, 464  
 Pupillary constrictor muscle, 509, 509f, 570, 579, 579f, 580f, 582, 609  
 Pupillary dilator muscle, 570, 580, 580f, 581f, 582, 609  
 Pupils, 578–584  
   accommodation response, 59, 60, 580  
   Adie's myotonic, 584  
   afferent defect, 59, 477, 583  
   Argyll Robertson, 163, 584  
   autonomic innervation of, 238f, 578–581  
   blown, 76, 145, 582, 647  
   in coma, 76, 647t  
   consensual response of, 59, 60, 579, 582, 582t, 583  
   direct response of, 59, 579, 582, 582t, 583  
   in Horner's syndrome, 582t, 582–583  
   Marcus Gunn, 583  
   in neurologic exam, 59–60, 76  
   in oculomotor nerve palsy, 576, 582  
   in Parinaud's syndrome, 590  
   in pons lesions, 583  
   swinging flashlight test of, 59, 477, 583  
   in vertebrobasilar ischemia, 657  
 Pure motor hemiparesis, 240–241, 261–263, 264f, 267f  
   in ischemic stroke, 404, 404t  
   in lacunar infarction, 261, 263  
   in pontine infarction, 262–263, 267f  
 Pure sensory stroke, 404t  
 Pure word deafness, 904–905  
 Purkinje cells, 704f, 705, 705f, 706, 706f, 707, 735  
 Putamen, 396f, 742, 744, 789  
   anterolateral view, 743f  
   and basal ganglia, 750f, 751f, 756f  
   blood supply of, 397f  
   in coronal section, 748f, 749f, 779f, 786f, 828f, 829f  
   CT image, 104f, 105f, 959f  
   and dopaminergic projection systems, 636, 636f  
   in horizontal section, 745f  
   lateral view, 743f, 746f  
   and lenticulostriate arteries, 395f  
   in motor system, 231f, 232f  
   MRI axial image, 111f, 264f, 302f, 783f, 788f  
   MRI coronal image, 114f, 115f  
   MRI sagittal image, 117f  
   in pathologic specimen, 189f  
   in sagittal section, 837f  
 Pyramid, 38f, 231f, 622f, 623f  
   and corticospinal tract, 234f, 235f, 268  
   MRI image, 108f  
   surface anatomy of, 498f, 499, 499f  
 Pyramidal cells, 835, 835f, 838  
 Pyramidal decussation, 32, 33f, 38f, 226f, 621, 623f  
   and cerebellar output pathways, 708f  
   and lateral corticospinal tract, 230f, 231f, 233, 234f, 268  
   surface anatomy of, 498f, 499  
   and weakness patterns, 241f, 242f, 243f, 244f, 245f, 246f  
 Pyramidal tract, 32, 233, 654f, 655f, 757. *See also* Corticospinal tract  
 Pyrrodoxime in myasthenia gravis, 328  
**Q**  
 Quadrantanopia, 465, 474, 474f, 475, 475f  
   left superior, 489f, 490  
 Quadriceps femoris muscle, 324t, 333t  
 Quadrigeminal cistern, 136, 137, 137f  
 Quadriplegia, 246–247  
**R**  
 Raccoon eyes, 75t, 156  
 Radial nerve, 358, 359f  
   and brachial plexus, 356f, 357, 357f  
   functions of, 323t, 358t, 360t, 385  
   neuropathy of, 363, 363f  
   to thumb muscles, 360  
 Radiation therapy, 158, 368  
 Radicular arteries, 227f, 227–228  
 Radicular pain, 286, 330  
 Radiculopathy, 326, 330t, 330–332, 350  
   pain in, 286, 330  
   surgical approaches to spine in, 333  
 Radiofrequency thermocoagulation, 771  
 Radiosurgery, stereotactic, 771  
 Random letter test, 931  
 Raphe nucleus, 637, 637f, 852  
   dorsal, 619f, 637f  
   median, 619f, 620f  
   in pain modulation, 280, 280f  
   serotonin in, 637, 638  
 Rapid alternating movements in neurologic exam, 69  
 Rapid eye movement (REM) sleep, 639, 639f, 640, 642  
   behavioral disorder in, 640, 766  
   in Parkinson's disease, 766  
 Rapid phase in nystagmus, 60  
 Rathke's pouch, 796, 796f  
 Reading, 895  
   in alexia, 902–903  
   assessment of, 55, 56, 897t  
   in Broca's aphasia, 898, 902  
   in dyslexia, 903  
   in hemineglect, 912  
   in Wernicke's aphasia, 899, 902  
 Recall memory, 844  
 Recent memory, 54, 844–845  
 Receptive aphasia, 43  
 Receptive fields in visual pathway, 461, 462, 463f  
   center-surround, 462, 463f, 469, 470f  
   of simple and complex cells, 469–470, 470f  
 Rectal examination, 10  
 Rectal sphincter muscle, 68, 295  
 Rectus femoris muscle, 324t  
 Rectus muscles of eye, 569f  
   inferior. *See* Inferior rectus muscle of eye  
   lateral. *See* Lateral rectus muscle of eye  
   medial. *See* Medial rectus muscle of eye  
   superior. *See* Superior rectus muscle of eye  
 Recurrent artery of Heubner, 118f, 395, 395f, 396f  
 Recurrent laryngeal nerve, 534, 535f, 537, 551–552, 554f  
 Red blood cells  
   in CSF, 169  
   sedimentation rate in temporal arteritis, 141  
 Red desaturation test, 59, 477  
 Red glass test, 574  
   in abducens palsy, 577, 578f  
   in oculomotor palsy, 575, 575f  
   in trochlear palsy, 576f, 577, 596  
 Red nucleus, 230, 232f, 234f, 617, 627  
   in axial section, 654f  
   and cerebellar output pathways, 708f, 709  
   magnocellular, 708f, 709  
   and oculomotor nerve, 571f  
   parvocellular, 619f, 708f, 709  
 Reduplicative paramnesia, 913  
 Reflexes  
   in coma, 74t, 77–79  
   corneal, 61, 77, 520  
   deep tendon, 37f, 37–38, 66–67, 67t  
   in frontal lobe lesions, 44, 68, 920  
   gag, 62, 77, 539, 540  
   jaw jerk, 61, 513, 520  
   in motor neuron lesions, 63t, 239t  
   in neurologic exam, 38, 51t, 66–68, 77–79, 81t  
   posturing, 77–78, 78f  
   primitive, 44, 68, 920  
   spinal nerve roots in, 67t, 68t  
   stretch, 37f, 37–38  
   vestibulo-ocular. *See* Vestibulo-ocular reflex  
 Reflex sympathetic dystrophy, 326  
 Refractive errors in vision, 472t  
 Reinforcement procedures in reflex testing, 66  
 Relational memory, 846  
 Relaxation times in MRI, 91–92  
 Relay nuclei of thalamus, 282t, 282–284  
 Release phenomenon, 472, 925  
 REM-off cells, 641f  
 REM-on cells, 640, 641f  
 Remote memory, 54, 845  
 REM sleep, 639, 639f, 640, 642  
   behavioral disorder in, 640, 766  
   in Parkinson's disease, 766  
 Reperfusion therapy in ischemic stroke, 406  
 Repetition tasks, 54–55, 897t  
   in Broca's aphasia, 897–898  
   in classification of aphasias, 900, 900f, 901  
   in Wernicke's aphasia, 899  
 Repetition time in MRI, 92  
 Repetitive stimulation in nerve conduction studies, 366, 381, 383f  
 Respiration, 648–649, 649f  
 Respiratory arrest, 648  
 Respiratory failure, mental status changes in, 939

- Responsive neurostimulation in epilepsy, 861
- Restiform body, 702
- Resting tremor, 762–763, 763t, 765
- Restless leg syndrome, 764
- Restraint, frontal lobe functions in, 914t, 916, 978
- Reticular activating system, 284, 285, 630
- Reticular formation, 40, 281, 284f, 285, 616, 616f, 628–629, 694 and basal ganglia, 751, 751f, 789 caudal, 40, 628, 629, 629f, 695 and cerebellar output pathways, 708f
- in consciousness system, 630
- functions of, 618t, 629, 632t
- medullary, 236f, 622f, 695
- midbrain, 131f, 571f, 589, 619f, 631f, 654f
- in pathologic specimen, 188f
- pontine. *See* Pontine reticular formation
- pontomedullary, 751
- pontomesencephalic, 41f, 630–631, 631f, 633
- rostral, 40, 589, 628, 629, 629f, 630, 694
- subcomponents of, 618t
- targets of, 632t
- and thalamus, 37f, 284f
- Reticular thalamic nucleus, 37f, 281, 281f, 283t, 285, 756, 756f
- in attention, 929
- in coronal section, 749f
- lateral, 622f
- Reticulospinal tract, 229t, 230, 233, 236f, 279f
- and cerebellar output pathways, 710
- in myelin-stained section, 623f
- Retina, 460–463, 474f, 492
- blood supply of, 476
- cellular layers of, 461, 462f
- formation of images on, 460, 460f
- ganglion cells of, 461–463
- ophthalmoscopic exam of, 58, 76, 470, 476
- photoreceptors in, 460, 461–462, 462f, 492
- Retinal artery, 476, 478–479
- Retinal vein, 476
- Retinohypothalamic tract, 800
- Retinotopic maps, 28, 466, 466f
- Retrochiasmal lesions, 473–474
- Retrograde amnesia, 54, 845, 845f, 847, 848, 882
- Retrosplenial cortex, 928f, 943f
- Reversible cerebral vasoconstriction syndrome, 141
- Review of systems, 6
- Rexed laminae, 224, 225f, 225t
- Rheumatic chorea, 760–761
- Rhinal sulcus, 25, 27f, 825, 826f, 837
- in coronal section, 828f, 829f, 835f
- MRI image, 879f
- and olfactory structures, 832f
- Rhinencephalon, 831
- Rhinorrhoea, CSF, 75t
- Rhombencephalon, 14, 15, 15f, 796f
- Rhomboid muscles, 323t
- Rhythmic ictal nonclonic hand motions, 856
- Ribs, 304f, 356f
- Right–left confusion, 55
- Right-way eyes, 591, 592f
- Rigidity, 758–759, 765, 766
- Rinne test, 528
- Rods, retinal, 461, 462f, 492
- Rolandic epilepsy, 860
- Romberg test, 70, 719
- Roof nuclei of cerebellum, 703, 703f
- Roof of fourth ventricle, 702f
- Rooting reflex, 44, 68, 920
- Rostral, 16, 16f, 17
- Rostral interstitial nucleus of MLF, 589, 610
- Rostral medulla, 234f, 235f, 275f, 621
- and anterolateral somatosensory pathways, 276f
- in myelin-stained section, 622f
- and posterior column somatosensory pathway, 275f
- sagittal view in situ, 701f
- and spinocerebellar pathways, 712f
- surface anatomy of, 499
- ventral, 280, 280f
- ventrolateral, 649
- Rostral nucleus solitarius, 504t, 505, 517f, 518, 532, 533f, 535, 563, 626
- Rostral pons
- blood supply of, 654f, 660t, 662
- MRI image, 725f
- and spinocerebellar pathways, 712f
- vascular syndromes of, 660t, 662
- Rostral raphe nuclei, 637
- Rostral reticular formation, 40, 628, 629, 629f, 694
- in consciousness system, 630
- in vertical eye movements, 589
- Rostral spinocerebellar tract, 710t, 711, 713
- Rostral thalamic intralaminar nuclei, 283t, 284, 630, 633
- Rostrum of corpus callosum, 25, 26f, 693f, 748f, 828f
- Round window, 521, 522f
- Rubral tremor, 719, 764
- Rubrospinal tract, 229, 229t, 230, 233, 234f, 279f
- and cerebellar output pathways, 708f
- in myelin-stained sections, 619f–623f
- S**
- Saccades, 60, 587
- in cerebellar lesions, 719
- frontal eye fields in, 591, 591f
- in frontal lobe disorders, 918t, 920
- in pseudocoma, 80
- Saccular aneurysm, 149, 152
- Sacculae, 521, 521f, 522f
- Sacral artery, ascending, 227f
- Sacral motor nuclei, and urinary function, 292f
- Sacral nerve roots, 22, 319, 320, 321f, 349, 350
- in cauda equina syndrome, 332–333
- CT myelogram of, 351f
- dermatomes of, 321, 322f
- and lumbosacral plexus, 357
- MRI image, 344f–345f
- muscles innervated by, 324t–325t
- radiculopathy of, 330, 332, 333t, 341–343, 344f–345f
- S1, 319, 321, 330, 332, 333t, 341–343, 344f–345f, 349, 350, 351f
- S2–S4, 349
- Sacral parasympathetic nuclei, 236f, 237f, 292f, 293t, 294
- Sacral sparing, 292
- Sacral spinal cord, 22f, 23f, 226f, 318, 318f
- and autonomic nervous system, 238f
- and corticospinal tract, 33f
- and somatosensory system, 288f, 289f
- and weakness patterns, 241f, 242f, 243f, 244f, 245f, 246f
- Sacrospinous ligament, 357f
- Sacrum, 346f, 357f
- Saddle anesthesia, 332, 347–349, 350f–351f
- Sagittal fissure, 25, 27f
- Sagittal images, 17, 86
- in MRI, 17, 116f–117f
- Sagittal plane, 17, 17f, 86
- Sagittal sinus
- CT image, 491f
- inferior, 17, 133f, 409, 410f, 452f, 559f, 957f
- MRI image, 607f
- superior. *See* Superior sagittal sinus
- thrombosis of, 411, 449–450, 451f–452f
- Salivation, 238f
- Salivatory nucleus
- inferior, 503f, 504, 504t, 509f, 532, 533f, 563, 624
- superior, 503f, 504, 504t, 509f, 515, 516f, 624
- Saltatory conduction, 19
- Saphenous nerve, 358f, 359f
- Sarcoidosis, 508, 541, 542f–543f
- Sartorius muscle, 324t
- Saturday night palsy, 363
- Scala tympani, 521, 522f
- Scala vestibuli, 521, 522f
- Scalp, 126f, 130
- CT image, 87f, 447f
- hemorrhage from, 156
- MRI image, 258f
- Scanning speech, 720
- Scapa's vestibular ganglia, 507t, 526
- Scapular nerve, dorsal, 323t, 356f, 357f
- Schaffer collateral fiber, 835f, 838
- Schizophrenia, 863, 938
- Schwann cells, 19
- Schwannoma, 158, 158t, 159
- hearing loss in, 528–529, 531, 550–551, 553f
- radiculopathy in, 332
- trigeminal, 529, 544–545, 547f–548f
- Sciatica, 365
- Sciatic nerve
- functions of, 324t, 361, 361t, 385
- and lumbosacral plexus, 357, 357f, 358f
- MRI image, 376, 378f
- neuropathy of, 361t, 364–365, 375–377, 376f, 378f
- Scotoma, 471, 472t, 473
- altitudinal, 476, 476f
- central, 477
- fortification, 139, 472
- homonymous, 475
- monocular, 473, 474f, 476, 476f
- Scout images, 86, 86f
- Screening neurologic exam, 52, 81, 81t
- Secondary headache, 139, 139t, 140–141
- Secondary sensory neurons, 34, 35, 35f
- in anterolateral pathways, 276f
- in posterior column pathway, 275f
- Secondary somatosensory cortex, 43f, 223f, 280
- Segmental organization of nervous system, 318–319
- Seizures, 850, 852–862
- absence, 857, 857t
- auditory hallucinations in, 926
- in brain tumors, 158, 859
- causes of, 858t, 859–860
- in cavernomas, 155, 156
- classification of, 853t, 853–858
- clinical manifestations in, 854t
- definition of, 852
- diagnosis of, 858–859
- focal onset, 853t, 853–856
- generalized onset, 853, 853t, 856–857
- in hypothalamic hamartoma, 800
- in ischemic stroke, 405
- in mass lesions, 142
- memory loss in, 847–848
- psychogenic nonepileptic, 79
- SPECT imaging in, 97f, 101
- in status epilepticus, 643t, 646, 857–858
- stereotactic procedures in, 771
- temporal lobe, 854t, 855–856
- tonic-clonic, 856–857
- treatment of, 858–862
- unknown or unclassified, 853, 853t
- wrong-way eyes in, 591
- Selective attention, 916, 926–927
- Sella turcica, 585f, 796f, 797
- Semantic dementia, 937
- Semicircular canals, 521, 525f, 525–526, 563
- anterior, 521f, 522f, 525f
- CT image, 128f, 549f
- horizontal, 525f
- lateral, 521f, 522f
- posterior, 521f, 522f, 525f
- Semicoma, 645–646
- Semilunar ganglion, 507t, 511
- Semimembranosus muscle, 324t
- Semitendinosus muscle, 324t
- Semont maneuver, 531
- Sensitization, 844
- Sensorimotor cortex, 101f
- Sensorimotor stroke, 404t
- Sensorineural hearing loss, 528
- Sensory aphasia, 43
- Sensory ataxia, 717–718
- Sensory columns of cranial nerve nuclei, 503, 504t, 505, 561
- Sensory cortex, 889t. *See also* Somatosensory cortex

- Sensory decussation, 35f  
 Sensory exam, 51t, 71–72  
   in coma, 74t, 77  
   in hemineglect, 72, 909–910  
   in screening, 81t  
 Sensory homunculus, 224f  
 Sensory level, 72, 286  
   in transverse cord lesions, 290–291  
 Sensory neglect, 56, 73, 909t, 909–912  
 Sensory nerve roots. *See* Dorsal nerve roots  
 Sensory nerves, 366  
 Sensory neurons, 18, 274  
   in anterolateral pathways, 276f  
   and dorsal nerve roots, 224  
   and dorsal root ganglia, 224, 274  
   in posterior column pathway, 275f  
   primary, 34, 35, 35f, 275f, 276f, 512f, 513  
   secondary, 34, 35, 35f, 275f, 276f  
   and spinal cord anatomy, 224, 225f  
   in stretch reflex, 38  
   types of, 274, 277t  
 Sensory nuclei, 617, 624  
   trigeminal, 503f, 505, 510f, 511t, 511–513, 512f, 562, 620f, 625  
 Sensory system, 273–313. *See also* Somatosensory system  
 Septal nuclei  
   in coronal section, 749f, 829f  
   lateral, 830, 841  
   medial, 634, 634f, 830, 841  
   medial view, 836f  
   MRI image, 115f, 482f, 818f  
 Septal region, 828f–829f, 830, 869f  
 Septic embolism, 403  
 Septum pellucidum, 26f  
   in coronal section, 748f, 749f, 828f, 829f  
   CT image, 105f, 106f, 178f, 184f, 194f, 211f, 491f  
   in horizontal section, 745f  
   MRI axial image, 111f, 206f, 429f, 731f  
   MRI coronal image, 114f, 115f, 543f, 817f, 868f  
 Sequencing tasks in mental status exam, 57, 57f, 918, 918t  
 Serotonin, 630, 637f, 637–638, 695  
   functions and location of, 20t, 632t, 637  
   receptors, 20t, 632t  
   in sleep–wake cycle, 640, 641f  
 Serratus anterior muscle, 323t  
 Setting sun sign in hydrocephalus, 157, 590  
 Sexual function, 295, 312  
   autonomic nervous system in, 238f, 293t, 295  
   pathways in, 293, 293t  
 Shadow artifact in CT scan, 102f  
 Sheehan's syndrome, 809  
 Shifting cognitive set tasks, 916  
 Shingles, 165, 331, 338  
 Short circumferential arteries, 651f, 652, 652f  
 Short posterior ciliary arteries, 476  
 Short-term memory, 845  
 Shy-Drager syndrome, 768  
 Sigmoid sinus, 132, 133f, 409, 410f, 454, 732f  
 Signal enhancement in attention, 927  
 Silent plantar response, 248  
 "Simian hand," 363f, 364  
 Similarities test of abstraction, 919, 919t  
 Simple cortical cells, 469–470, 470f  
 Simultanagnosia, 925  
 Single photon emission computed tomography (SPECT), 100, 101  
   in Parkinson's disease, 101, 765f, 766  
   in seizures, 97f, 101  
 Sinus intercavernosus, 811f  
 Sinus rectus. *See* Straight sinus  
 Skew deviation, 530, 577  
 Skills, learning and memory of, 843f, 843–844  
 Skin  
   CT image, 87f, 102f, 177f  
   examination of, 10  
   MRI image, 108f, 109f, 487f  
   of scalp, 126f  
 Skip lesions in carotid stenosis, 424f  
 Skull, 126, 126f, 128  
   craniotomy of, 169–170  
   CT image, 172f, 185f, 447f  
   foramen in, 126, 127f–128f, 500, 501f, 502t  
   MRI image, 109f, 258f  
   shape of, in frontal lobe disorders, 918t, 920  
 Sleep  
   compared to coma, 643, 643t  
   and hypersomnia, 801  
   hypothalamus functions in, 800–801  
   and insomnia, 801  
   memory of dreams in, 849  
   in Parkinson's disease, 766  
   periodic leg movements in, 764  
   rapid eye movements in, 639, 639f, 640, 642, 766  
 Sleep–wake cycle, 638–642  
   norepinephrine in, 636, 637  
   stages of sleep in, 638–639, 639f  
 Slow phase in nystagmus, 60  
 Small-vessel infarction, 403, 404, 405  
 Smell sense. *See* Olfaction  
 Smooth pursuit eye movements, 60, 587, 591  
 Snellen notation, 470  
 Snout reflex, 44, 68, 920  
 Social history, 6  
 Sodium levels in hyponatremia, 808, 812  
 Soft palate, 535f  
 Soleus muscle, 324t  
 Solitary nucleus. *See* Nucleus solitarius  
 Solitary tract, 622f, 626, 655f  
 Somatic afferents, 502f, 503f  
 Somatic efferents, 236, 237f  
   general, 502f, 503f  
 Somatic motor column, 503f  
 Somatic motor functional category, 506t, 508, 537  
 Somatic motor nuclei, 502f, 504, 504t, 624  
 Somatic sensory nuclei, 502f  
 Somatization disorder, 58, 79  
 Somatoform disorders, 643t, 646  
 Somatomedins, 804  
 Somatosensory cortex, 280  
   and anterolateral pathways, 276f  
   association, 43f, 222, 280, 890f  
   and cortical sensory loss, 280, 288  
   and homunculus, 28, 29f, 222, 224f  
   and posterior column pathway, 275f, 278  
   primary. *See* Primary somatosensory cortex  
   secondary, 43f, 223f, 280  
   sensory loss in lesions of, 280  
   and thalamus connections, 285f  
   and trigeminal sensory system, 512f  
 Somatosensory homunculus, 28, 29f, 222, 224f  
 Somatosensory radiation, 231f, 278, 279, 289  
 Somatosensory system, 34–37, 273–313  
   anterolateral pathways in. *See* Anterolateral somatosensory pathways  
   assessment of, 51t, 71–72, 77, 81t  
   long tracts in, 222, 222t, 274, 274t  
   motor system inputs, 228  
   in multiple sclerosis, 251t  
   patterns and localization of sensory loss, 288–290  
   posterior column pathways in. *See* Posterior column somatosensory pathway  
   spinal cord in, 35f, 36f, 286–288  
   thalamus in, 35–37, 275f–276f, 280–285, 312  
   topographic organization of, 28, 29f, 277–278, 278f, 312  
 Somatotopic organization, 28–29, 29f, 222, 224, 267, 312  
   of anterolateral pathway, 278f  
   of corticobulbar tract, 232f  
   of corticospinal tract, 232f, 233  
   homunculus in, 28–29, 29f, 222, 224f  
   of medial and lateral motor systems, 229f  
   of multimodal inputs to cerebellum, 711f  
   of posterior column pathway, 277–278, 278f  
   of spinal trigeminal nucleus, 513f  
 Spasmodic dysphonia, 759  
 Spastic bladder, 294, 294f  
 Spastic catch, 248  
 Spasticity, 239, 757  
   gait in, 249t  
 Spatial akinesia, 910  
 Spatial processing, 44, 906, 907  
   hippocampus in, 846  
   visual pathways in, 467–468, 468f, 492  
 Special senses, 505  
 Special somatic afferent (SSA), 502f, 503f, 504t, 625  
 Special somatic sensory column, 503f  
 Special somatic sensory functional category, 506t, 507, 508, 520  
 Special somatic sensory nuclei, 505, 625  
 Special visceral afferent (SVA), 502f, 503f, 504t, 505, 626  
 Special visceral efferent (SVE), 502f, 503f, 504t, 624  
 Special visceral sensory functional category, 506t  
   facial nerve in, 515, 516  
   glossopharyngeal nerve in, 532  
   vagus nerve in, 534, 535  
 SPECT imaging, 100, 101  
   in Parkinson's disease, 101, 765f, 766  
   in seizures, 97f, 101  
 Speech  
   assessment of, 54–55, 897, 897t  
   in Broca's aphasia, 897–898  
   in cerebellar disorders, 720  
   dysarthria of, 538–539  
   fluency of, 897, 897t, 900, 900f, 901  
   muscles of articulation in, 62–63  
   neurologic exam in impairment of, 73  
   paraphasic errors in, 54, 899  
   in Parkinson's disease, 766  
   primary motor cortex in, 895  
   scanning or explosive, 720  
   in vocal tics, 761  
   in Wernicke's aphasia, 899  
 Sphenoid bone, 127f, 129f, 796f  
 Sphenoid sinus, 585f, 797  
   midsagittal view, 496f  
   MRI axial image, 109f, 868f  
   MRI coronal image, 115f, 482f, 543f, 602f  
   MRI sagittal image, 116f  
 Sphenopalatine ganglion, 507t, 509f, 516, 516f  
 Sphincter muscles  
   anal, 68, 295  
   in spinal cord disorders, 286  
   urethral, 292f, 293t, 294  
 Spinal accessory nerve (CN XI), 323t, 507t, 536, 563  
   and brainstem, 38f, 39f  
   cranial root of, 536  
   disorders of, 537–538  
   exit foramen, 500, 501f, 502t  
   fascicles of, 623f  
   functional category, 506t, 536  
   functions of, 40t, 63, 497t  
   motor nucleus of, 503f  
   surface anatomy of, 498f, 499f, 500  
 Spinal accessory nucleus, 503f, 504, 504t, 536, 563, 621, 623f, 624  
 Spinal arterial plexus, 227, 227f  
 Spinal arteries, 227, 227f  
   anterior, 45f, 46, 227, 227f, 228, 267, 392f, 651f  
   posterior, 46, 227, 227f, 267  
 Spinal canal, 319, 320f  
   lateral recess of, 320, 320f, 321f  
   MRI image, 344f  
   stenosis of, 329t, 331  
 Spinal cord, 14, 14f, 15t, 22f, 22–23  
   anterior cord syndrome, 291f, 292, 309–310, 312f–313f  
   basic anatomy of, 224–227, 225f, 267  
   blood supply to, 46, 227f, 227–228, 267, 287  
   and brainstem, 38f, 39f  
   central canal of, 22f, 135f, 318f, 622f

- central cord syndrome, 290f–291f, 291–292
- cervical. *See* Cervical spinal cord
- in coma and related states, 643t, 644f
- compression of, 287, 301–305, 304f, 306f
- and corticospinal tract, 33, 33f, 234f, 235f
- CT image, 304f
- differential diagnosis of disorders, 287t
- embryonic development of, 14, 15f
- gait in disorders of, 717
- gray matter in, 21, 21f, 22f, 23, 33, 224, 225, 225f, 267, 318f
- hemispheric lesions of, 290f, 291
- in horizontal section, 232f
- infarction of, 287
- lesions of, 286–288, 287t, 290–292
- lumbar. *See* Lumbar spinal cord
- meninges of, 132
- midsagittal view, 496f
- motor dysfunction in disorders of, 286
- MRI axial image, 306f, 313f
- MRI diffusion-weighted image, 669f
- MRI sagittal image, 116f, 306f, 310f, 312f
- in myelin-stained section, 226f
- in pain modulation, 280f
- posterior cord syndrome, 291f, 292
- in reflexes, 37f, 68
- relation to spine, 22f, 318, 318f, 320f, 349
- and rubrospinal tract, 234f
- sacral. *See* Sacral spinal cord
- sagittal view in situ, 701f
- sensory level in disorders of, 286
- sensory loss patterns in disorders of, 290
- in somatosensory system, 35f, 36f, 286–288
- subacute combined degeneration of, 939
- surface anatomy of, 26f, 498f, 499f
- syndromes of, 290f–291f, 290–292
- thoracic. *See* Thoracic spinal cord
- transverse cord lesions, 290f, 290–291
- trauma of, 286–287
- and vestibulospinal tract, 235f
- weakness patterns in lesions of, 244, 246
- white matter in, 21, 21f, 22f, 224, 225, 225f, 267, 318f
- Spinal muscular atrophy, 252
- Spinal nerve roots, 22, 317–351
- in arm, 332, 332f, 332t
- in bladder function, 293t
- in bowel function, 293t
- cervical. *See* Cervical nerve roots
- and dermatomes, 321, 322f
- dorsal (sensory). *See* Dorsal nerve roots
- in leg, 332, 332f, 333t
- lumbar. *See* Lumbar nerve roots
- MRI image, 344f
- muscles innervated to, 322, 323t–325t
- radiculopathy of, 326, 330–332
- in reflexes, 67t, 68t
- sacral. *See* Sacral nerve roots
- in sexual function, 293t
- thoracic. *See* Thoracic nerve roots
- ventral (motor). *See* Ventral nerve roots
- Spinal nerves, 14f, 15t, 22, 22f, 23, 318f, 320f
- mixed, 319
- and somatic efferents, 237f
- and spinal cord anatomy, 225f
- Spinal shock, 286–287, 649
- Spinal trigeminal nucleus, 502f, 503f, 511, 512f, 513, 516f, 625
- in axial section, 655f
- and facial nerve, 513f, 516f
- functions of, 511t
- and glossopharyngeal nerve, 533f
- in myelin-stained section, 621f, 622f, 623f
- somatotopic maps of, 513f
- and vagus nerve, 535f
- Spinal trigeminal tract, 226f, 512f, 513, 625
- in axial section, 655f
- in myelin-stained section, 621f, 622f, 623f
- Spine, 320f
- cervical. *See* Cervical spine
- CT image, 304f
- CT myelography, 88–89, 331
- degenerative disorders of, 287, 329t
- fractures of, 147, 301–302, 304f
- lumbar, 321f, 333, 346f, 357f
- MRI image, 330–331
- myelogram of, 346f
- percussion of, 330, 331f
- physical examination of, 9, 330, 331f
- relation to spinal cord, 22f, 318, 318f, 320f, 349
- sacral, 346f, 357f
- surgical approaches to, 333
- thoracic, 301–302, 304f, 306f, 333, 356f
- Spin echo sequence in MRI, 92
- Spinocerebellar ataxia, 722, 733–734, 736f–737f, 769
- Spinocerebellar fibers, 711
- Spinocerebellar tract, 712f
- dorsal, 279f, 622f, 623f, 710t, 711, 712f
- rostral, 710t, 711, 713
- ventral, 279f, 620f–623f, 710t, 711, 712f, 713
- Spin of protons in MRI, 90, 91f
- Spinomesencephalic tract, 276f, 278, 279
- Spinoreticular tract, 276f, 278, 279
- Spinothalamic tract, 35, 36f, 274, 276f, 278–279, 311, 626, 694
- in axial section, 654f, 655f
- input to thalamus, 284f
- and trigeminal sensory system, 512f
- Spinous process, vertebral, 304f, 319, 320f
- Spiral computed tomography, 87
- Spiral computed tomography angiography, 99
- Spiral ganglion, 507t, 522f, 523, 523f
- Spirochetal infections, 163
- Splenium of corpus callosum, 25, 26f
- CT image, 105f, 443f, 491f, 960f
- in horizontal section, 745f
- MRI axial image, 111f, 788f, 952f
- MRI coronal image, 114f, 732f
- MRI sagittal image, 116f, 693f
- Spondylolisthesis, 329t
- Spondylolysis, 329t
- Spondylopathy, 329t
- Spontaneous speech, 54
- Spreading depression in migraine, 139
- Spreading of reflexes, 66
- Spurling's maneuver, 330
- Stage curtain sign, 539
- Stance, assessment of, 70
- Stapedius muscle, 515, 516f, 522f
- Stapes, 521, 522f
- Staring spells, 857t
- Static encephalopathy, 934, 938
- Statin therapy, 407
- Status epilepticus, 643t, 646, 857–858
- Steele–Richardson–Olszewski syndrome, 768
- Stellate cells, 705f, 706, 706f, 707, 735
- Stellate cervical ganglia, 236, 238f, 581f
- Stenosis
- of basilar artery, 657, 671, 674f, 676, 682f
- of internal carotid artery, 407, 408–409, 423, 424f, 476, 478–479
- of spinal canal, 329t, 331
- Stereognosis, 72
- Stereotactic procedures, 170, 771–773
- in brain tumors, 158
- in epilepsy, 771, 861
- external reference systems in, 771
- in Parkinson's disease, 780–781, 782f–783f
- Sternocleidomastoid muscle, 63, 536
- Steroid therapy in brain tumors, 158
- Stomach, 238f
- Strabismus, 574
- Straight-leg raising test, 9, 330, 331f
- Straight sinus, 133f, 409, 410f
- CT image, 89f
- magnetic resonance venography of, 452f
- MRI image, 110f, 116f, 484f, 731f
- Stratum lacunosum moleculare, 835f
- Stratum oriens, 835f
- Stratum pyramidale, 835f
- Stratum radiatum, 835f
- Strength testing, 64–65, 65t–66t, 80
- Streptococcal meningitis, 161t
- Stress incontinence, 294f
- Stretch reflex, 37f, 37–38
- Stria medullaris, 745f, 749f, 831t, 852
- Stria of Gennari, 466–467, 467f
- Striatal pathways, 750
- Stria terminalis, 804, 819, 831t
- and amygdala, 850f, 851
- bed nucleus of, 828, 829f, 830, 849
- in coronal section, 748f, 749f, 829f
- Striatonigral degeneration, 784, 786f–787f
- Striatum, 742, 742t, 744, 750, 830
- Striosomes, 750
- Stroke, 390, 398–407
- ischemic. *See* Cerebral ischemia and infarction
- pure sensory, 404t
- risk factors for, 405, 405t, 407
- sensorimotor, 404t
- in transient ischemic attack, 402
- in vertebrobasilar disease, 657–658
- Stroop test, 918t, 919
- Stupor, 643t, 645–646
- Styloid process, 102f, 128f, 549f
- Stylomastoid foramen, 500, 501f, 502t, 515, 516f
- CT image, 128f, 549f
- Stylopharyngeus muscle, 532, 533f
- Subacute mental status changes, 933t
- Subarachnoid hemorrhage, 149–153, 154, 176t
- in aneurysm rupture, 149–153, 411–413, 417f–418f
- angiography in, 412, 417f–418f
- cerebral vasospasm in, 153
- CSF in, 169
- CT image, 151f, 152–153, 178f, 412, 417f
- headache in, 140–141, 149, 153, 411–413
- in interhemispheric fissure, 412, 417f
- in Sylvian fissure, 412, 417f
- Subarachnoid space, 126f, 131, 132
- cisterns in, 136–137
- in coronal section, 748f, 828f
- CSF in, 134f, 136–137, 320f
- in lumbar puncture, 168, 168f
- MRI image, 693f, 817f
- Subcallosal gyrus, 826f
- Subclavian artery, 45f, 122f, 391, 391f, 603f
- Subclavian vein, 45f
- Subclavius, nerve to, 356f, 357f
- Subcommissural organ, 138, 138f
- Subcortical structures, 894f, 896, 928–930
- Subdural empyema, 162
- Subdural hematoma, 148–149, 176t
- acute, 149, 150f, 173–180, 196f
- chronic, 148–149, 150f, 170–173, 938
- CT image, 149, 150f, 172f, 177f–179f, 196f
- hematocrit effect in, 149, 151f
- hypodense, 172f
- isodense, 149, 150f
- Subdural space, 126f, 131–132
- Subfalcine herniation, 146f, 147, 190–195, 196f
- Subfornical organ, 138f
- Subgaleal hemorrhage, 156, 176t, 177f, 196f
- Subiculum, 834, 837, 838f, 839–840, 841, 882

- in coronal section, 749f, 835f  
 embryonic development of, 834f  
 layers of, 835, 835f, 838  
 medial view, 836f  
 MRI image, 117f, 879f  
 in sagittal section, 837f  
 Sublingual gland, 509f, 516f  
 Submandibular ganglion, 507t,  
 509f, 516, 516f  
 Submandibular gland, 509f, 516f  
 Suboccipital craniotomy, 170  
 Subscapularis muscle, 323t  
 Subscapular nerve, 323t, 356f, 357,  
 357f  
 Substance P, 280, 752, 752f  
 Substantia gelatinosa, 225f, 225t,  
 623f  
 Substantia innominata, 115f, 748f,  
 829f, 830  
 Substantia nigra, 232f, 619f, 654f,  
 742, 789  
 in coronal section, 747, 749f  
 and oculomotor nerve, 571f  
 in Parkinson's disease, 747, 753,  
 765, 765f  
 pars compacta, 635f, 635–636,  
 747, 750, 750f, 752f, 765, 789  
 pars reticulata, 284f, 747, 750,  
 750f, 751, 751f, 789  
 in pathologic specimen, 188f  
 and thalamus, 284f  
 Subthalamic fasciculus, 756f, 757  
 Subthalamic nucleus, 742, 747,  
 752f, 756f, 789  
 in coronal section, 749f, 799f  
 deep brain stimulation of, 772,  
 780–781, 782f  
 MRI image, 776f, 782f  
 Sucking reflex, 44, 68, 920  
 Sudden infant death syndrome,  
 637  
 Sudden unexpected death in  
 epilepsy, 637, 860  
 Sulci, cerebral, 24, 25  
 Sulcus limitans, 502f, 617  
 Sundowning phenomenon, 933,  
 936  
 Superficial cerebral veins, 409, 410,  
 410f, 454  
 Superficial fibular nerve  
 functions of, 325t, 361, 361t, 385  
 and lumbosacral plexus, 358f  
 neuropathy of, 361t  
 and regions of sensory  
 innervation, 359f  
 Superior, 16f, 16–17  
 Superior anastomotic vein of  
 Trolard, 410, 410f  
 Superior articular process,  
 vertebral, 319, 320f  
 Superior cerebellar artery, 45f, 46,  
 393f, 713–714, 714f  
 aneurysm of, 152f  
 angiography of, 119f, 683f, 692f  
 in axial section, 654f  
 and brainstem blood supply,  
 650, 651f, 652, 653f  
 and circle of Willis, 392f  
 infarction of, 662, 715, 722–723,  
 725f–726f  
 lateral view, 701f  
 MRA image, 120f  
 MRI image, 114f, 725f, 726f  
 and oculomotor nerve, 571f  
 syndrome of, 659, 660t, 662  
 territory of, 714f  
 in vertebrobasilar system, 650,  
 652  
 Superior cerebellar peduncle, 17,  
 39f, 619f, 627, 702, 735  
 in axial section, 654f  
 and cerebellar input pathways,  
 712f  
 and cerebellar output pathways,  
 708f  
 decussation of, 573f, 617, 619f,  
 620f, 627, 702  
 and deep cerebellar nuclei, 703f  
 dorsal view, 702f  
 lateral view, 701f  
 MRI image, 114f, 725f  
 in myelin-stained section, 620f,  
 621f  
 surface anatomy of, 498f, 499,  
 499f  
 ventral view, 702f  
 Superior cervical ganglia, 236,  
 238f, 580, 581f  
 Superior colliculus, 39f, 617, 751  
 and anterolateral  
 somatosensory pathways,  
 276f  
 in attention, 930  
 and basal ganglia, 751, 751f  
 brachium of. *See* Brachium of  
 superior colliculus  
 CT image, 104f  
 and descending motor  
 pathways, 236f  
 in eye movements, 590  
 and hypercolumn, 471f  
 MRI image, 110f, 114f, 732f  
 in myelin-stained section, 619f  
 and oculomotor nerve, 571f  
 surface anatomy of, 497, 498f,  
 499f  
 and thalamus, 284f  
 in visual pathway, 464, 464f  
 Superior division MCA infarction,  
 897, 898, 905, 905f  
 CT image, 256f–257f  
 left, 253–254, 256f–257f, 398t,  
 425–426, 429f, 948–950, 952f  
 MRI image, 429f, 952f  
 right, 399t, 435–436  
 Superior division of oculomotor  
 nerve, 570, 576  
 Superior dorsolateral pons, 653  
 Superior frontal gyrus, 25, 26f, 27f  
 CT image, 104f, 105f, 106f, 107f,  
 431f, 444f  
 MRI axial image, 111f, 112f, 113f,  
 298f–299f, 429f, 448f, 952f  
 MRI coronal image, 115f, 542f,  
 869f  
 three-D surface reconstruction,  
 97f  
 Superior frontal sulcus, 25, 26f, 27f  
 CT image, 106f, 107f  
 MRI image, 112f, 113f, 299f  
 three-D surface reconstruction,  
 97f  
 Superior glossopharyngeal  
 ganglion, 507t, 532, 533f  
 Superior gluteal nerve, 325t, 357f,  
 358f  
 Superior hypophysial arteries,  
 801, 802f  
 Superior laryngeal nerve, 534, 535f  
 Superior medullary velum, 620f  
 Superior mesenteric ganglion, 238f  
 Superior oblique muscle of eye,  
 568, 569f, 570t, 609  
 innervation of, 570, 570t  
 MRI image, 542f  
 Superior olivary nuclear complex,  
 621f, 625  
 and auditory pathways, 523f,  
 524, 524f  
 Superior orbital fissure, 500, 501f,  
 502t, 509, 609  
 and trigeminal nerve, 510f, 511,  
 562  
 Superior parietal lobule, 25, 26f,  
 27f, 43  
 in attention, 928f  
 CT image, 106f, 107f  
 MRI image, 112f, 113f  
 in somatosensory system, 280  
 three-D surface reconstruction,  
 97f  
 Superior petrosal sinus, 133f, 409,  
 410f  
 Superior rectus muscle of eye, 568,  
 569f, 570t, 609  
 CT image, 103f  
 innervation of, 570, 570t, 572f,  
 572t  
 MRI image, 110f, 542f  
 in vertical eye movements, 589  
 Superior sagittal sinus, 17, 133f,  
 409, 410f, 454  
 and circulation of CSF, 134f  
 CT image, axial, 89f, 105f–106f,  
 184f, 211f, 444f  
 CT image, in parietal  
 hemorrhage, 451f  
 CT image, in subdural  
 hematoma, 172f, 178f, 179f  
 CT image, with horizontal  
 slices, 256f  
 magnetic resonance venography  
 of, 452f  
 MRI axial image, 110f, 112f,  
 258f, 298f, 429f, 680f, 689f  
 MRI coronal image, 96f, 114f,  
 115f, 547f, 726f, 732f, 957f  
 MRI sagittal image, 199f, 611f  
 and protective layers of brain,  
 126f  
 venous blood in, 134f  
 Superior salivatory nucleus, 503f,  
 504, 504t, 509f, 515, 516f, 624  
 Superior tarsal muscle, 580–581  
 Superior temporal gyrus, 25, 26f,  
 114f, 523f, 976f  
 Superior temporal sulcus, 25, 26f,  
 952f  
 Superior thalamic radiation, 231f  
 Superior vagal ganglion, 507t,  
 535f, 536  
 Superior vestibular ganglion, 522f,  
 526  
 Superior vestibular nerve, 521f,  
 522f  
 Superior vestibular nucleus, 526f,  
 527, 620f, 621f, 625, 703f  
 Supinator muscle, 323t  
 Supplementary eye fields, 755f  
 Supplementary motor area, 222,  
 223f, 755f, 915f  
 and association cortex, 43f  
 in attention, 928f  
 and language areas, 894f  
 and thalamus connections, 285f  
 Suprachiasmatic nucleus, 798f,  
 799, 799f  
 in circadian rhythms, 799, 800,  
 819  
 Supraclavicular nerves, 359f  
 Supraclinooid segment of internal  
 carotid artery, 118f, 391f, 392  
 Supramammillary nucleus, 633  
 Supramarginal gyrus, 25, 26f, 894f  
 Supranuclear control of eye  
 movements, 586–593, 610  
 Supranuclear palsy, progressive,  
 589, 768  
 Supraoptic decussation, 749f, 829f  
 Supraoptic nucleus, 798f, 799, 803,  
 819  
 in coronal section, 748f, 749f,  
 799f, 829f  
 magnocellular portion, 802f, 820  
 Supraoptico-hypophysial tract,  
 802f  
 Supraoptic recess, 135f  
 Supraoptic region, 798, 819  
 Suprapineal recess, 135f, 157  
 Suprascapular nerve, 323t, 356f,  
 357f  
 Supraspinatus muscle, 323t  
 Supratentorial dura, 130, 139, 511,  
 540  
 Sural nerve, 358f, 359f, 361t  
 Susceptibility-weighted MRI, 95,  
 96  
 Suspended sensory loss in central  
 cord syndrome, 291–292  
 Sustained attention, 926, 927,  
 930–932  
 Swallowing, 539  
 Sweat glands, 237, 238f  
 Swinging flashlight test, 59, 477,  
 583  
 Sydenham's chorea, 760–761, 863  
 Sylvian fissure, 24, 24f, 26f, 890f,  
 952f  
 and circle of Willis, 392f  
 and cortical functional areas,  
 390f, 915f  
 CT image, 104f–105f, 179f, 210f,  
 417f, 431f, 443f, 958f–959f  
 deep middle cerebral vein in,  
 410f  
 hemorrhage in, 412, 417f, 955,  
 958f–959f  
 and limbic system, 42f, 826f  
 MRI axial image, 110f, 429f,  
 611f, 731f, 952f, 954f  
 MRI coronal diffusion-weighted  
 image, 448f, 688f  
 MRI coronal T1-weighted  
 image, 114f–115f, 482f, 543f,  
 547f, 602f, 776f, 878f, 957f,  
 976f  
 MRI sagittal image, 976f  
 primary auditory cortex in, 28f  
 Sylvian point, 118f  
 Sylvian triangle, 118f  
 Sylvius aqueduct. *See* Cerebral  
 aqueduct of Sylvius  
 Sympathetic ganglia, 23f, 236, 237f  
 Sympathetic nervous system, 15t,  
 23f, 23–24, 236–237, 238f, 268  
 in bladder function, 293t  
 efferents in, 237f  
 fibers in cavernous sinus, 585  
 functions of, 23f, 23–24, 236  
 neurotransmitters in, 237

- in pupillary dilation, 580–581, 581f, 609
  - in sexual function, 293t, 295
  - Sympathetic trunk, 236, 238f, 600–601, 603f
  - Synapses, 19, 138
  - Synaptic cleft, 18f
  - Synaptic plasticity, 839
  - Synaptic vesicles, 18f, 19
  - Syncope, 402
  - Synkinesis in facial nerve lesions, 520
  - Syntax, 895, 898
  - Syphilis, 163, 584, 939
  - Syringomyelia, 305–307, 308f
  - Systems review, 6
- T**
- T1 relaxation in MRI, 91–92
  - T1-weighted MRI images, 92, 92t, 93f, 94, 95
    - axial, 102f–107f
    - coronal, 114f–115f
    - sagittal, 116f–117f
  - T2 relaxation in MRI, 91–92
  - T2-weighted MRI images, 92, 92t, 93f, 94, 95
  - Tabes dorsalis, 163
  - Tabetic gait, 250t
  - Tactile extinction, 61, 72, 909
  - Tactile hemineglect, 909
  - Tactile response test, 910
  - Tail of caudate nucleus, 744
    - anterolateral view, 743f
    - in coronal section, 749f
    - in horizontal section, 745f
    - lateral view, 743f, 746f
    - MRI image, 114f
    - in sagittal section, 837f
  - Tandem gait, 71, 719, 723
  - Tapeworm infections, 166
  - Tardive dyskinesia, 759
  - Tardy ulnar palsy, 364
  - Tarsal muscle, superior, 580–581
  - Task-negative attention networks, 928f, 929, 979
  - Task-positive attention networks, 928f, 929, 979
  - Task-related brain signals, 928, 928f
  - Taste cortex, 517f, 518
  - Taste sense, 540, 694
    - central pathways in, 517f, 518
    - deficit in, 62
    - facial nerve in, 515, 516, 516f, 517f, 518
    - glossopharyngeal nerve in, 532, 533f
    - testing of, 61
    - tongue in, 516f, 533f, 540
    - vagus nerve in, 535, 535f
  - Tau protein, 937, 940
  - TDP-43 protein, 937, 938
  - Technetium-99m SPECT imaging, 97f, 100
  - Tectorial membrane, 521, 522f
  - Tectospinal tract, 229t, 230, 233, 236f, 279f
    - in myelin-stained section, 619f–623f
  - Tectum, 15f, 617, 617f
    - and basal ganglia, 789
    - and cerebellar output pathways, 708f, 710
    - MRI image, 116f, 976f
  - sagittal view in situ, 701f
  - surface anatomy of, 497
  - Tegmental area
    - lateral, 636, 636f, 637
    - ventral, 619f, 635, 635f, 636, 755
  - Tegmental decussation, ventral, 234f, 708f
  - Tegmental nuclei, 620f, 634, 634f
  - Tegmentum, 15f, 617, 617f
    - CT image, 104f
    - MRI image, 110f, 689f
    - pontine, 588, 621, 925–926
    - vascular syndromes of, 660t, 661, 662, 662t
    - wrong-way eyes in lesions of, 592, 607f, 661
  - Telangiectasias, capillary, 156
  - Telencephalon, 14–15, 15f
  - Temperature sense
    - anterolateral pathway in, 34, 35, 36f, 274, 274t, 278, 278f, 279, 311
    - assessment of, 71
    - loss of, 289
    - sensory neuron fiber types in, 277t
  - Temporal arteritis, 141, 476
  - Temporal artery, 141
  - Temporal association cortex, 890f
  - Temporal bone, 127f
    - CT image, 103f, 185f, 210f
    - fractures of, 181, 182, 185f, 546, 549f
    - petrous. *See* Petrous temporal bone
  - Temporal branch of facial nerve, 515, 516f
  - Temporal craniotomy, 170
  - Temporal gyrus
    - inferior, 25, 26f, 27f, 114f
    - middle, 25, 26f, 114f
    - superior, 25, 26f, 114f, 523f, 976f
  - Temporal horn of lateral ventricle, 110f, 135f, 136, 136f, 835f
    - in coronal section, 749f, 829f
    - CT image, 103f, 177f, 178f, 184f, 193f, 417f, 443f
    - embryonic development of, 834f
    - lateral view, 746f
    - MRI axial image, 110f, 201f, 421f
    - MRI coronal image, 114f, 206f, 868f, 878f
    - MRI sagittal image, 117f
    - in sagittal section, 837f
  - Temporalis muscle, 87f, 177f, 510f
  - Temporal lobe, 24, 24f, 25, 41, 43
    - astrocytoma of, 483, 484f
    - atrophy of, 937
    - blood supply of, 397f
    - and cerebral arteries, 393f
    - in coronal section, 786f
    - corticopontine fibers from, 619f
    - CT image, axial, 210f, 420f, 431f, 443f, 691f, 729f, 965f, 970f, 975f
    - CT image, axial, in intracranial hemorrhage, 193f, 958f
    - CT image, axial, normal appearance, 102f–105f
    - CT image, in basilar artery thrombosis, 682f
    - CT image, in subdural hematoma, 177f
    - in frontotemporal lobar degeneration, 937
    - glioblastoma multiforme of, 871–875, 878f
    - lateral view, 746f
    - lymphoma of, 866–867, 868f–869f
    - medial memory areas, 833, 834, 841, 842–843, 845
    - in middle cranial fossa, 128, 129f, 131f
    - MRI axial diffusion-weighted image, 673f, 688f, 725f
    - MRI axial proton density-weighted image, 547f, 608f
    - MRI axial T1-weighted image, 109f–110f, 546f, 553f, 560f, 561f, 601f, 611f, 731f, 868f
    - MRI axial T1-weighted image with contrast, 484f
    - MRI axial T2-weighted image, 267f, 421f, 429f, 602f, 607f, 680f–681f, 689f, 725f, 842f, 954f
    - MRI coronal diffusion-weighted image, 448f, 688f
    - MRI coronal T1-weighted image, 482f, 543f, 547f, 778f, 842f, 868f–869f, 878f, 957f, 976f
    - MRI coronal T1-weighted image, normal appearance, 115f
    - MRI sagittal image, 117f, 952f, 976f
    - and optic radiations, 465f
    - seizures in disorders of, 854t, 855–856
  - Temporal pole, 26f, 27f
    - in limbic system, 42f, 824t, 825, 826f, 881
    - MRI image, 115f, 827f
  - Temporal sulcus, 952f
    - inferior, 25, 26f, 832f
    - superior, 25, 26f, 952f
  - Temporoammonic pathway, 838
  - Temporomandibular joint, 549f
  - Temporoparietal cortex, 954f
  - Tensilon test in myasthenia gravis, 327, 380
  - Tension-type headache, 140
  - Tensor fasciae latae, 325t
  - Tensor tympani muscle, 510f, 514, 522f
  - Tentorial herniation, 145–146, 146f
  - Tentorial incisura (notch), 130, 131f
    - herniation through, 145–146
  - Tentorium cerebelli, 130, 130f, 131f
    - and cerebral venous drainage, 410f
    - CT image, 89f, 184f, 193f, 443f, 682f
    - CT image, in subdural hematoma, 177f, 178f
    - CT image, normal appearance, 103f–104f
    - and dural venous sinuses, 133f
    - and herniation syndromes, 146f
    - midsagittal view, 496f
    - MRI axial image, 109f–110f, 673f, 725f, 736f, 827f
    - MRI coronal image, 487f, 726f
    - MRI normal image, 109f–110f, 116f–117f, 736f
    - MRI sagittal image, 116f–117f
    - and oculomotor nerve, 571f, 575
    - sagittal view in situ, 701f
  - Teres major and minor muscles, 323t
  - Terminal ganglia, 236, 237f, 534
  - Terminal vein, 749f, 829f
  - Testosterone, 803f
  - Tetraparesis, 246–247
  - Tetraplegia, 246–247
  - Thalamic fasciculus, 707, 749f, 751, 756, 756f
  - Thalamic peduncle, 231f, 831t
  - Thalamic radiation, 231f
  - Thalamocapsular lacunar infarction, 404t
  - Thalamocortical connections, 36, 37f
  - Thalamoperforator arteries, 396f
  - Thalamus, 15, 15f, 21, 21f, 757
    - and anterolateral pathways, 276f
    - anterolateral view, 743f
    - in arousal, 630, 631, 631f
    - and basal ganglia, 744, 745f, 746f, 748f–749f, 751f, 756f
    - blood supply of, 396f, 397f, 650, 653
    - and brainstem, 38f, 39f, 41f, 497
    - and cerebellar output pathways, 708f, 709
    - in consciousness system, 943f
    - in coronal section, 748f–749f, 786f, 799f
    - CT image, 179f, 184f, 431f, 432f, 443f, 491f, 691f, 959f, 968f
    - CT image, normal appearance, 104f–105f
    - endoscopic view, 207f–208f
    - hemorrhage from, 154, 590, 592
    - in horizontal section, 745f
    - infarction of, 687, 691f
    - internal medullary lamina of, 750, 750f
    - lacunar infarction of, 300–301, 302f, 404, 404t
    - lateral view, 746f
    - and level of consciousness, 40–41, 41f
    - medial view, 797f
    - midsagittal view, 496f
    - in motor system, 228, 228f, 232f
    - MRI axial FLAIR image, 788f
    - MRI axial proton density-weighted image, 264f
    - MRI axial T1-weighted image, 110f–111f, 199f, 200f, 731f
    - MRI axial T2-weighted image, 429f, 783f, 827f
    - MRI coronal image, 114f, 264f, 776f, 817f
    - MRI parasagittal image, 422f
    - MRI sagittal image, 116f, 117f, 560f, 611f, 782f
    - noncortical inputs to, 284f
    - nuclei in, 36, 37f, 281f, 281–285, 282t–283t
    - and optic radiations, 465f
    - and posterior column pathway, 275f
    - prefrontal cortex connections, 915
    - pulvinar of. *See* Pulvinar
    - reciprocal connections with cerebral cortex, 36, 37f, 285, 285f
    - sensory loss patterns in lesions of, 289

- in sleep-wake cycle, 641f  
in somatosensory system, 35–37, 275f–276f, 280–285, 312  
surface anatomy of, 26f, 498f, 499f  
and visual pathways, 464, 464f  
Thalmo-geniculate arteries, 396f  
Thalmo-perforator arteries, 119f, 395  
Thecal sac, 319, 320f  
Thenar eminence, 360  
Thermoregulation, 801  
Thiamine deficiency, 847, 869–871, 872f–873f  
Third ventricle, 16, 132, 135f, 136  
and circulation of CSF, 134f  
colloid cyst of, 203–205, 206f–208f  
in coronal section, 748f, 749f, 799f, 829f  
CT image, 104f, 210f  
embryonic development of, 796f  
endoscopic view, 208f  
in horizontal section, 745f  
location of, 136t  
MRI axial image, 110f–111f, 199f, 200f, 202f, 731f  
MRI coronal image, 114f, 206f, 547f, 776f, 817f, 818f, 872f  
MRI sagittal image, 202f  
ventriculostomy in hydrocephalus, 157  
Thirst, 801  
Thoracic intervertebral disc, 306f, 333, 341  
Thoracic nerve roots, 22, 319, 349, 350  
angiographic image, 603f  
and brachial plexus, 356, 356f  
dermatomes of, 321, 322f  
muscles innervated by, 323t–324t  
and pupillary dilation, 581f  
T1, 330, 340–341, 356  
T4, 349  
T10, 349  
Thoracic nerves  
cutaneous rami of, 359f  
long, 323t, 356f, 357f  
Thoracic outlet syndrome, 362  
Thoracic radicular artery, 227f  
Thoracic spinal cord, 22f, 23f, 226f, 227, 318, 318f  
and autonomic nervous system, 238f  
and corticospinal tract, 33f  
and somatosensory system, 288f, 289f  
vulnerable zone of, 228, 287  
and weakness patterns, 241f, 242f, 243f, 244f, 245f, 246f  
Thoracic spine, 301–302, 304f, 306f, 333, 356f  
Thoracodorsal nerve, 323t, 356f, 357, 357f  
Thoracolumbar nervous system, 236, 268. *See also* Sympathetic nervous system  
Three-dimensional surface reconstructions of MRI scans, 96, 97f  
Thrombectomy, 99, 406, 434, 441f–442f  
Thrombolytic agents in stroke, 406  
Thrombosis, 403, 405, 406, 656  
of basilar artery, 657, 662, 676, 677–678, 682f–683f  
in posterior circulation, 656  
sagittal sinus, 411, 449–450, 451f–452f  
venous, 411  
Thumb, 360  
Thunderclap headache, 140–141  
Thymectomy in myasthenia gravis, 328  
Thymoma, 328, 381  
Thyroid gland, 804  
hyperthyroidism, 806–807, 939  
hypothyroidism, 768t, 769, 807, 808, 939  
Thyroid hormones, 803f  
Thyroid-stimulating hormone, 801, 802t, 820  
adenoma secretion of, 804, 806–807  
deficiency of, 808  
functions of, 803f, 804  
Thyroxine, 803f, 804  
Tibialis muscles, 324t, 325t  
Tibial nerve  
functions of, 324t, 361, 361t, 385  
and lumbosacral plexus, 357, 357f, 358f  
neuropathy of, 361t  
Tic, 761–762  
douloureux, 140, 141, 514  
Tight junctions, 137, 137f  
Tinel's sign, 363  
Tinnitus, 528, 925  
Tissue plasminogen activator, 406  
Titubation, 719  
Todd's paresis, 855  
Tone of muscles, 63t, 64, 721  
in motor neuron lesions, 239, 239t  
Tongue, 537  
MRI image, 482f  
muscles of, 63  
in taste sense, 516f, 533f, 540  
Tonic-clonic seizures, 856–857  
Tonic contractions in seizures, 855, 856  
Tonotopic maps, 28, 523  
Tonsillar herniation, 146f, 146–147  
with uncus herniation, 187–190, 191–194f  
Tonsils, cerebellar  
CT image, 102f, 191f, 192f  
herniation of, 146f, 146–147, 187–190, 191–194f  
MRI image, 108f, 116f, 693f  
sagittal view in situ, 701f  
ventral view, 702f  
Top-down attention networks, 928f, 929, 979  
Top-of-the-basilar syndrome, 663, 685–687, 691f–692f  
Topographic organization, 28–29, 29f  
Torcular Herophili, 409, 410f, 452f, 701f, 732f  
Torsional eye movements, 568, 569  
Torticollis, 759  
Touch sense  
anterolateral pathway in, 34, 274, 274t, 279, 311  
facial, 61  
posterior column pathway in, 34, 274, 274t, 275f, 311  
sensory neuron fiber types in, 277t  
in tactile extinction, 61, 72, 909  
in tactile hemineglect, 909  
in tactile response test, 910  
testing of, 61, 71–72  
Tourette's syndrome, 761–762, 863  
Toxic exposures, 859, 933t, 934, 940  
Toxoplasmosis, 162, 165–166, 773–774, 776f  
Tracts in CNS, 21  
Transcortical aphasia, 900f, 901, 902, 978  
Transient global amnesia, 848  
Transient ischemic attacks, 401–402, 402t  
in carotid stenosis, 408, 423, 424f  
of retina, 476  
Transitional cortex, 827, 828t  
Transsphenoidal approach, 170, 805, 811–812  
Transtentorial herniation, 145–146, 146f  
Transverse cord lesions, 290f, 290–291  
Transverse gyri of Heschl, 28, 42f  
and auditory pathways, 523f, 524f  
MRI image, 117f, 976f  
Transverse myelitis, 165, 251  
Transverse process, vertebral, 319, 320f  
Transverse section, 17, 17f  
Transverse sinus, 133f, 409, 410f, 454, 732f  
Trapezius muscle, 63, 323t, 536  
Trapezoid body, 523f, 524, 524f, 621f  
Trauma  
back pain in, 329t  
of head. *See* Head trauma  
headache in, 140, 147  
of lower extremity nerves, 364–365  
in lumbar puncture, 169  
radiculopathy in, 331  
of spinal cord, 286–287  
syringomyelia in, 307  
of upper extremity nerves, 362–364  
Tremors, 762–764  
action or intention, 719, 762, 763, 763t  
in ataxia, 719, 764  
in cerebellar lesions, 719, 764  
deep brain stimulation in, 772–773  
essential, 719, 763, 772–773  
flapping, 762  
observation of, in motor exam, 64  
in Parkinson's disease, 753, 763, 765, 766  
postural, 719, 762, 763t, 763–764  
resting, 762–763, 763t, 765  
rubral, 719, 764  
in Wilson's disease, 760, 764, 769  
Triceps brachii muscle, 37f, 67t, 323t, 332t  
Triceps surae muscle, 324t  
Trigeminal autonomic cephalgia, 140  
Trigeminal ganglion, 501f, 507t, 510f, 511, 512f  
Trigeminal lemniscus, 278, 512, 512f, 562  
in myelin-stained section, 619f–621f  
and thalamus, 284f  
Trigeminal nerve (CN V), 139, 321, 562  
in articulation, 62–63  
in axial section, 654f  
and brainstem, 38f, 39f  
disorders of, 514  
exit foramen, 500, 501f, 502t  
in facial sensations, 321, 514  
fascicles of, 620f  
functional category, 506t, 510  
functions of, 40t, 497t, 511–514  
function testing, 61, 62–63, 77  
in jaw jerk reflex, 61, 513  
mandibular division, 500, 501f, 510, 510f, 511, 513f, 562  
maxillary division, 500, 501f, 510, 510f, 511, 513f, 562  
motor nuclei and pathways, 503f, 504, 504t, 510f, 514  
motor root of, 501f, 510, 510f, 514, 562  
MRI image, 547f, 602f, 725f  
neuralgia of, 140, 141, 514  
ophthalmic division, 500, 501f, 510, 510f, 511, 513f, 562, 585, 585f, 586  
peripheral and parasympathetic ganglia, 507t  
regions of sensory innervation, 359f  
sensory nuclei and pathways, 503f, 505, 510f, 511–513, 512f, 514  
surface anatomy of, 498f, 499f, 500  
Trigeminal neuralgia, 140, 141, 514  
Trigeminal neuroma, 529  
Trigeminal nuclei, 504t, 505, 625  
mesencephalic. *See* Mesencephalic trigeminal nucleus  
motor, 503f, 504, 504t, 510f, 514, 620f, 624  
sensory, 503f, 505, 510f, 511t, 511–513, 512f, 562, 620f, 625  
spinal. *See* Spinal trigeminal nucleus  
Trigeminal schwannoma, 529, 544–545, 547f–548f  
Trigeminothalamic tract, 279, 512, 512f, 513, 562  
input to thalamus, 284f  
in myelin-stained section, 619f, 620f  
Trigone of lateral ventricle, 136, 136t. *See also* Atrium of lateral ventricle  
Triiodothyronine, 803f, 804  
Triple flexion, 78, 78f  
Triple H therapy in cerebral vasospasm, 153  
Trisynaptic pathway, 838, 882  
Trochlea, 568  
Trochlear nerve (CN IV), 507t, 508–509, 562, 609  
and brainstem, 38f, 39f  
and cavernous sinus, 585.585f, 586  
descending fascicles of, 573f

- exit foramen, 500, 501f, 502t  
in extraocular movements, 60,  
76, 568, 570, 570t, 571–572  
fascicles of, 573f, 619f  
functional category, 506t, 508  
functions of, 40t, 497t  
in situ view, 571f, 573f  
motor nucleus of, 503f  
palsy of, 576f, 576–577  
surface anatomy of, 498f, 499f,  
500
- Trochlear nuclei, 504, 570, 571–572,  
572f, 609, 617, 624  
and functional columns of  
brainstem, 503f  
functions of, 504t  
in situ view, 573f  
in myelin-stained section,  
619f and vestibular tracts, 526f
- Trochlear palsy, 576f, 576–577,  
596–597
- Truncal ataxia, 69, 70, 71, 717, 719,  
735
- Tuberal hypothalamic region, 799,  
799f, 819
- Tuber cinereum, 796, 797f
- Tuberculous meningitis, 161t, 162,  
165
- Tubero-infundibular tract, 802f
- Tuberomammillary nucleus, 638,  
638f
- Tufted cells, 832, 832f, 881
- Tuning fork tests, 62, 71, 528
- Two-point discrimination, 72
- Tympanic cavity, 549f
- Tympanic membrane, 521, 522f
- Tympanic nerve, 532
- U**
- Ulnar claw, 363f, 364
- Ulnar groove, 364
- Ulnar nerve, 358  
and brachial plexus, 356f, 357,  
357f  
compound motor action  
potential of, 366f, 373, 381,  
383f  
entrapment at elbow, 364, 373  
functions of, 358t, 385  
muscles innervated by, 324t,  
360, 360t, 361  
neuropathy of, 363f, 364  
region of sensory innervation,  
359f, 373f
- Ultrasound, 98–99  
Doppler, 98–99, 407  
MRI-guided focused, 781, 783f
- Uncal herniation, 145–146, 146f,  
180–190  
in epidural hematoma, 180–183,  
184f–185f  
in glioblastoma, 183–187,  
188f–189f  
with tonsillar herniation,  
187–190, 191–194f
- Uncinate fasciculus, 708f, 709, 831t,  
850f, 851  
in coronal section, 748f, 749f,  
829f
- Uncooperative patient, neurologic  
exam in, 73, 74
- Uncus, 27f, 828  
in coronal section, 748f, 829f  
CT image, 177f, 178f, 193f
- herniation of. *See* Uncal  
herniation  
in limbic system, 42f, 825, 826f  
MRI image, 827f, 878f  
in pathologic specimen, 188f
- Unimodal association cortex, 42,  
889, 889t, 890f, 891, 977
- Unipolar neurons, 19
- Upgaze, 589  
in Parinaud's syndrome, 157,  
590, 606–607
- Upper extremity  
bilateral weakness or paralysis,  
245, 246–247  
flexor posturing of, 78, 78f  
nerve roots in, 332, 332f, 332t,  
350  
nerves in, 358t, 358–359,  
362–364, 385  
strength testing of, 65t  
unilateral weakness or  
paralysis, 240–243
- Upper motor neurons, 33f, 33–34,  
228, 268  
cerebellar exam in disorders  
of, 718  
in descending pathways, 229  
facial weakness in lesions of,  
61–62, 244f, 244–245, 518,  
519f, 520, 562  
and lateral corticospinal tract,  
230f  
in muscle tone, 63t, 64  
signs of lesions, 63t, 64, 239,  
239t, 252  
spinal accessory nerve  
disorders, 536  
for tongue, 537  
and trigeminal motor functions,  
514
- Upper trunk of brachial plexus,  
356f
- Urethra, 292f, 293t, 294
- Urge incontinence, 294, 294f
- Urinary function, 294f, 294–295  
micturition centers in, 292f, 294,  
915f  
pathways in, 292f, 293t
- Urinary incontinence, 294f,  
294–295  
in anterior cord syndrome, 292  
in frontal lobe disorders, 44, 918  
in hydrocephalus, 157  
in syphilis, 163
- Urinary retention, 294, 294f, 295
- Urinary urgency, 294
- Urine, post-void residual volume,  
294
- Utilization behavior, 917
- Utricle, 521, 521f, 522f
- V**
- Vagal ganglion, 507t, 535f, 536
- Vagal trigone, 39f, 498f, 499, 534,  
625
- Vagus nerve (CN X), 139, 509f,  
534–536, 563  
in bowel function, 293t, 295  
and brainstem, 38f, 39f  
disorders of, 537–538  
dorsal motor nucleus of. *See*  
Dorsal motor nucleus of  
vagus nerve  
exit foramen, 500, 501f, 502t  
fascicles of, 655f  
functional category, 506t, 534  
functions of, 23f, 40t, 62–63, 77,  
497t, 534  
in myelin-stained section, 622f  
peripheral and parasympathetic  
ganglia, 507t  
sensory and motor pathways,  
535f  
sensory nucleus of, 503f  
and spinal trigeminal nucleus,  
513f  
stimulation in epilepsy  
treatment, 861, 862  
surface anatomy of, 498f, 499f,  
500
- Valvular heart disease, 403
- Varicella-zoster virus infections,  
165, 331
- Vascular dementia, 938, 979
- Vascular malformations, 155–156
- Vasculitis, 141, 476
- Vasogenic edema, 139, 142
- Vasopressin. *See* Antidiuretic  
hormone
- Vasospasm, cerebral, 153
- Vastus muscles, 324t
- Vegetative state, 643, 643t, 644f,  
645
- Venography, magnetic resonance,  
99
- Ventral, 16, 16f, 17
- Ventral amygdalofugal pathway,  
749f, 800, 819, 829f, 831t, 850f,  
851
- Ventral anterior nucleus, 281f, 751,  
752f, 772, 789
- Ventral caudal nucleus, 772
- Ventral cochlear nucleus, 503f, 523,  
523f, 524, 524f, 562, 625
- Ventral column of spinal cord  
(anterior), 22f, 225, 225f, 235f,  
318f
- Ventral horn of spinal cord, 17, 22f,  
224, 225f, 225t, 226f, 294, 318f  
and corticospinal tract, 33, 33f,  
268  
functions associated with, 292f,  
293t  
and somatic efferents, 236, 237f
- Ventral intermediate nucleus, 772
- Ventral lateral nucleus, 281f, 282t,  
283, 751, 752f, 772, 789  
and cerebellar output pathways,  
707, 708f  
in coronal section, 749f
- Ventral lateral preoptic area, 639,  
800  
in sleep–wake cycle, 639, 640,  
641f
- Ventral medial nucleus, 282t, 798f,  
799, 799f
- Ventral medial prefrontal cortex,  
928f
- Ventral medial temporal  
association cortex, 890f
- Ventral median fissure of spinal  
cord, 22f, 318f
- Ventral nerve roots, 22, 22f, 23,  
226f, 267, 318f, 349  
and basic spinal cord anatomy,  
224, 225f  
and somatic efferents, 237f  
in stretch reflex, 37f
- Ventral oculomotor nucleus, 572f,  
572t
- Ventral oral nucleus, 772
- Ventral pallidum, 748f, 755, 829f,  
830
- Ventral pathways in visual  
processing, 468, 468f, 492,  
921, 922, 979
- Ventral pons, 868f
- Ventral posterior lateral nucleus,  
281f, 282t, 283, 311, 772  
sensory loss in lesions of, 289  
and somatosensory pathways,  
35f, 36f, 275f–276f, 278, 279
- Ventral posterior medial nucleus,  
281f, 282t, 283, 772  
sensory loss in lesions of, 289  
and taste pathways, 517f, 518  
and trigeminal sensory  
pathways, 512, 512f, 513
- Ventral spinocerebellar tract, 279f,  
710t, 711, 712f, 713  
in myelin-stained section,  
620f–623f
- Ventral striatal pathways, 754
- Ventral striatum, 744, 830
- Ventral tegmental area, 619f, 635,  
635f, 636, 755
- Ventral tegmental decussation,  
234f, 708f
- Ventricles, cerebral, 14, 16, 132–136  
fourth. *See* Fourth ventricle  
hemorrhage in, 155  
lateral. *See* Lateral ventricle  
structure of, 135f  
third. *See* Third ventricle
- Ventricular drain, external, in  
hydrocephalus, 157
- Ventriculoperitoneal shunt in  
hydrocephalus, 157, 963, 966f
- Ventriculostomy, in  
hydrocephalus, 157, 447f
- Verbal apraxia, 904
- Verbal memory, 843
- Vergence eye movements, 587,  
590, 610
- Vermis, cerebellar, 700, 703, 703t,  
707, 735  
dorsal view, 702f  
inferior, 708f, 709t, 710  
lung metastasis in, 723–724, 729f  
MRI image, 602f, 732f  
output pathways, 707, 708f, 709,  
709t, 710  
and urinary function, 292f
- Vertebrae, 301–302, 319, 320f  
CT image, 304f  
in lumbar puncture, 168, 168f
- Vertebral arteries, 44, 45f, 227, 391,  
391f, 453, 650  
aneurysm of, 152f  
angiography of, 119f, 603f, 683f,  
692f  
in axial section, 655f  
and brainstem blood supply,  
650, 651f, 653f  
and circle of Willis, 392f  
CT image, 102f, 192f  
dissection of, 403, 409, 657,  
663–665, 667f–668f  
extracranial, 119f, 121f, 391f  
intracranial, 119f, 121f, 391f  
lateral view, 701f  
left, 227f  
MRA image, 120f, 121f, 122f  
MRI image, 108f, 337f,  
667f–668f, 679f, 680f, 726f

- right, 227f  
stenosis of, 657  
thrombosis of, 657
- Vertebral body, 304f, 306f, 319, 320f, 321f
- Vertebral foramen, 319, 320f. *See also* Spinal canal
- Vertebrobasilar system, 152, 531, 650–663, 656t, 656–663
- Vertical diplopia, 576–577, 596–597
- Vertical eye movements, 587, 589–590, 610, 768
- Vertiginous gait, 249t
- Vertigo, 62, 249t, 529–531, 530t
- Vestibular ganglion, 522f, 526, 710t, 713  
of Scarpa, 507t, 526
- Vestibular nerve, 521f, 522f, 531
- Vestibular neuritis, 531
- Vestibular nuclei, 502f, 525, 526f, 526–527, 563, 625–626  
in axial section, 655f  
and cerebellar pathways, 708f, 710t, 713, 735  
and deep cerebellar nuclei, 703f, 704, 704f  
in eye movements, 592–593  
and functional columns of brainstem, 503f  
functions of, 504t  
inferior, 526f, 527, 622f, 625–626  
lateral, 235f, 526f, 527, 621f, 625, 703f  
medial, 235f, 526f, 527, 621f, 622f, 625, 703f  
MRI image, 873f  
in myelin-stained section, 621f, 622f  
superior, 526f, 527, 620f, 621f, 625, 703f
- Vestibular sense, 540  
assessment of, 62  
pathways in, 525–527  
in spatial analysis, 907
- Vestibule of ear, 521
- Vestibulocerebellum, 527, 710
- Vestibulocochlear nerve (CN VIII), 520–531, 562–563  
auditory pathways, 521–525, 523f, 524f  
and brainstem, 38f, 39f  
disorders of, 527–531  
exit foramen, 500, 501f, 502t  
functional category, 506t, 520  
functions of, 40t, 497t  
function testing of, 62, 76  
MRI image, 109f, 553f, 674f, 736f  
peripheral and parasympathetic ganglia, 507t  
sensory nucleus of, 503f  
surface anatomy of, 498f, 499f, 500  
vestibular pathways, 525–527
- Vestibulo-ocular reflex, 62, 527, 587, 593, 610  
in cerebellar disorders, 719–720  
in coma, 76–77  
suppression test, 593, 720
- Vestibulospinal tracts, 229t, 230, 233, 235f  
and cerebellar output pathways, 710
- lateral, 229t, 235f, 279f, 526f, 527, 622f, 623f  
medial, 229t, 235f, 279f, 526f, 527, 622f, 623f  
pontine, 279f
- Vibration sense  
assessment of, 71  
loss of, 289  
midline change in, 80  
posterior column pathway in, 34, 35f, 274, 274t, 275f, 278f, 311  
sensory neuron fiber types in, 277t
- Videostroboscopic imaging, 552, 554f
- Vigilance, testing of, 931
- Viral infections, 164–166  
HIV, HIV infection and AIDS  
meningitis in, 160, 161t, 164
- Virchow–Robin space, 131
- Visceral afferents, 626  
general, 502f, 503f  
special, 502f, 503f
- Visceral efferents  
general, 502f, 503f  
special, 502f, 503f
- Visceral motor nuclei, 502f, 504, 504t
- Visceral sensory column, 503f, 505
- Visceral sensory functional category, 506t  
facial nerve in, 515  
glossopharyngeal nerve in, 532  
vagus nerve in, 534
- Visceral sensory nuclei, 502f
- Vision, 459–492  
assessment of, 58–59, 60, 76  
in diplopia. *See* Diplopia disorders of, 470–475  
intracranial pressure increase affecting, 143
- Visual acuity, testing of, 58, 470–471
- Visual agnosias, 923–924
- Visual cortex  
association, 43f, 44, 464, 468, 468f, 477, 492, 890f, 921–922  
columnar organization of, 468–470  
CT image, 105f, 960f  
in eye movements, 591, 591f  
infarction of, 967–968, 970f  
MRI image, 110f, 111f  
primary. *See* Primary visual cortex  
and pupillary responses, 579f, 580  
and thalamus connections, 285f
- Visual evoked potentials, 477
- Visual extinction, 59, 909
- Visual fields, 28–29, 460f, 461, 470, 471, 489–490, 492  
bitemporal defects, 463, 492  
homonymous defects, 463, 471, 472t, 473–474, 474f, 492  
in intracranial pressure increase, 143  
localization of defects, 472–475  
monocular defects, 463, 492  
normal, 461f  
and retinotopic maps, 466, 466f  
testing of, 59, 76, 473, 483f, 485f  
in Wernicke’s aphasia, 899
- Visual hallucinations, 472, 472t
- Visual hemineglect, 909
- Visual mental imagery, 922
- Visual phenomenon, 471–472, 472t
- Visual processing, 921–925  
dorsal pathways in, 468, 468f, 492, 921, 922, 979  
ventral pathways in, 468, 468f, 492, 921, 922, 979
- Visual reorientation, 924
- Visual scene description in neglect, 912, 913
- Visual-spatial analysis, 806, 907, 913
- Visual system, 459–492  
blood supply of, 476–477  
disorders of, 470–475  
dorsal processing pathways in, 468, 468f, 492, 921, 922, 979  
extrageniculate pathways in, 464, 464f  
higher-order processing in, 921–925  
lateral geniculate nucleus in, 464f, 464–465, 465f  
ventral processing pathways in, 468, 468f, 492, 921, 922, 979
- Vital signs, 9
- Vitamin deficiency, 847, 869–871, 872f–873f, 939
- Vitreous, 103f, 110f, 484f
- Vitreous humor, 462f
- Vocal cords, 538, 551–552, 554f
- Vocal tics, 761, 762
- Voice disorders, 538, 766
- Voiding reflex, 294
- Vomiting, 143, 650
- von Economo’s encephalitis lethargica, 769
- Vulnerable zone of thoracic spinal cord, 228, 287
- W**
- Wada test, 100, 101, 858–859, 905–906
- “Waiter’s tip” pose, 362, 362f
- Wallenberg’s syndrome, 658t, 659, 663–665, 667f–668f
- Wallerian degeneration, 326
- Water, MRI image, 92, 93f, 94, 94f
- Watershed zones of cerebral arteries, 400–401, 444–445, 454, 477, 901  
angiography of, 118f  
in axial section, 401f  
in coronal section, 401f  
language areas in, 898f  
MRI image, 448f
- Waxy rigidity, 759
- Weakness  
generalized, 247  
Hoover test in, 80  
in motor neuron lesions, 63t, 239, 239t, 244f, 252  
patterns and localization of, 240–247, 268  
psychogenic, 80  
terms describing, 240, 240t
- Weber’s syndrome, 662t
- Weber test, 528
- Werdnig–Hoffmann disease, 252
- Wernicke–Korsakoff syndrome, 847, 869–871, 872f–873f, 912
- Wernicke’s aphasia, 43, 899, 978  
classification of, 900, 900f  
in MCA infarction, 427–428, 899, 951, 954f  
recovery in, 902
- Wernicke’s area, 43, 43f, 390, 390f, 894f, 894–895, 978  
BOLD fMRI mapping of, 101f  
CT image, 958f, 959f  
in MCA infarction, 905f, 954f
- White blood cells, CSF, 161t, 169
- White matter, 15f, 21, 21f  
of cerebellum, 702, 704f, 705f  
CT image, 87f, 88t  
embryonic development of, 834f  
and hypercolumn, 471f  
MRI image, 92, 93f, 94f, 109f  
network connections, 833–834  
optic radiations in, 390, 390f  
of spinal cord, 21, 21f, 22f, 224, 225, 225f, 267, 318f
- White ramus, 237f  
communicantes, 580, 581f
- Widespread project systems, 632t, 632–638
- Wiesel, Torsten, 468, 469, 470
- Wilson’s disease, 759–760, 769  
dementia in, 939  
tremors in, 760, 764, 769
- Window parameter in CT, 89
- Wisconsin Card Sorting Test, 916
- Witzelsucht, 917
- Word generation tasks in frontal lobe disorders, 918t, 919
- Working memory, 844, 844t, 916
- Wrist drop in radial neuropathy, 363, 363f
- Writer’s cramp, 759
- Writing skills  
in agraphia, 55, 902–903  
assessment of, 55, 56, 57f, 897t  
in Broca’s aphasia, 898, 902  
in hemineglect, 912  
in Wernicke’s aphasia, 899, 902
- Wrong-way eyes, 591–592, 592f, 604, 607f  
in basilar artery thrombosis, 677–678, 682f–683f  
in vertebrobasilar ischemia, 657, 660t, 661
- X**
- Xanthochromia, 169
- X-rays, compared to computed tomography, 86
- Z**
- Zona incerta, 749f, 756, 756f
- Zygomatic arch, 127f
- Zygomatic branch of facial nerve, 515, 516f



