THOMAS A. WOOLSEY
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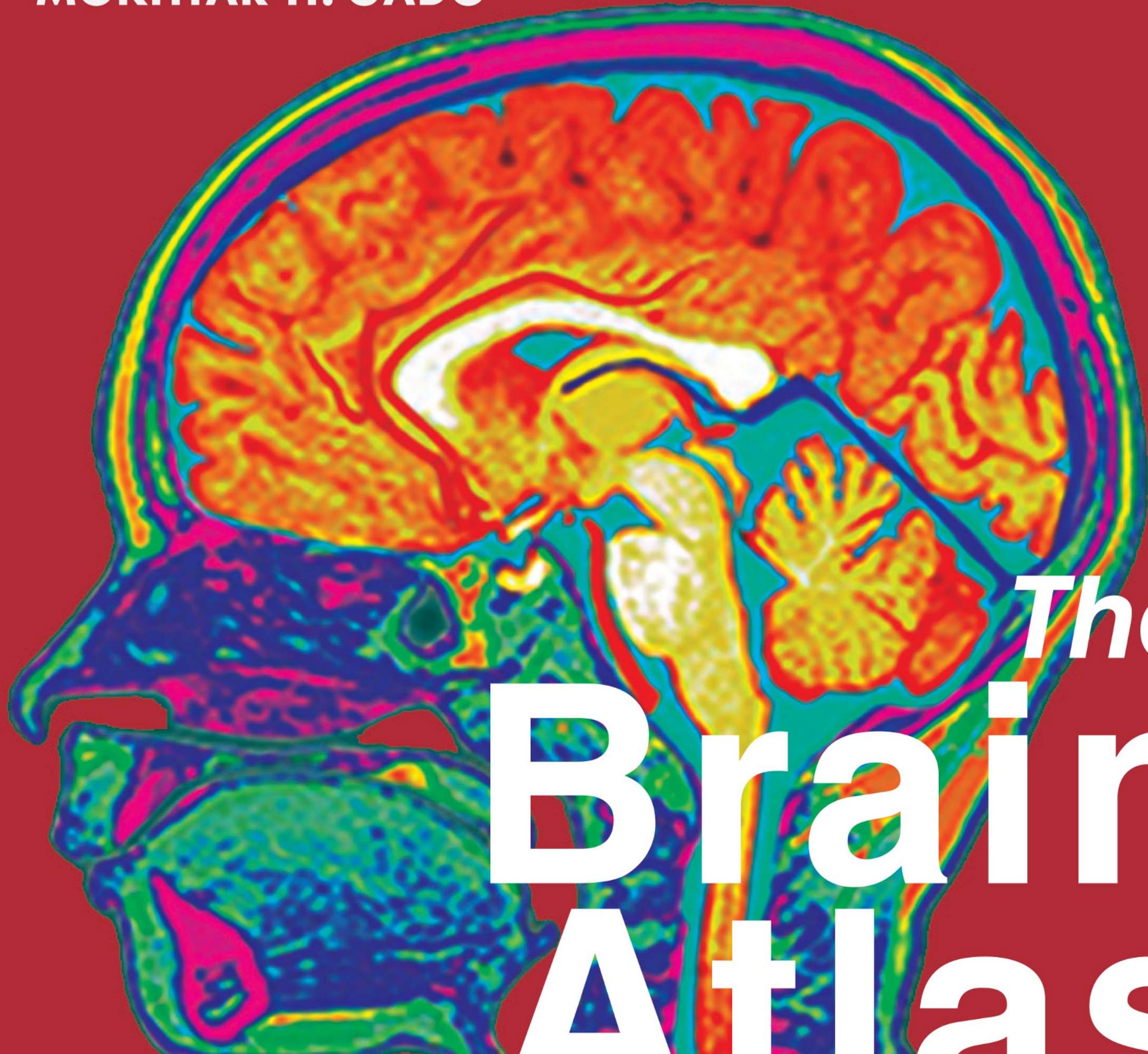
MOKHTAR H. GADO

FOURTH EDITION



The Brain Atlas

A VISUAL GUIDE TO THE HUMAN CENTRAL NERVOUS SYSTEM

digital companion

WILEY Blackwell

FOURTH EDITION

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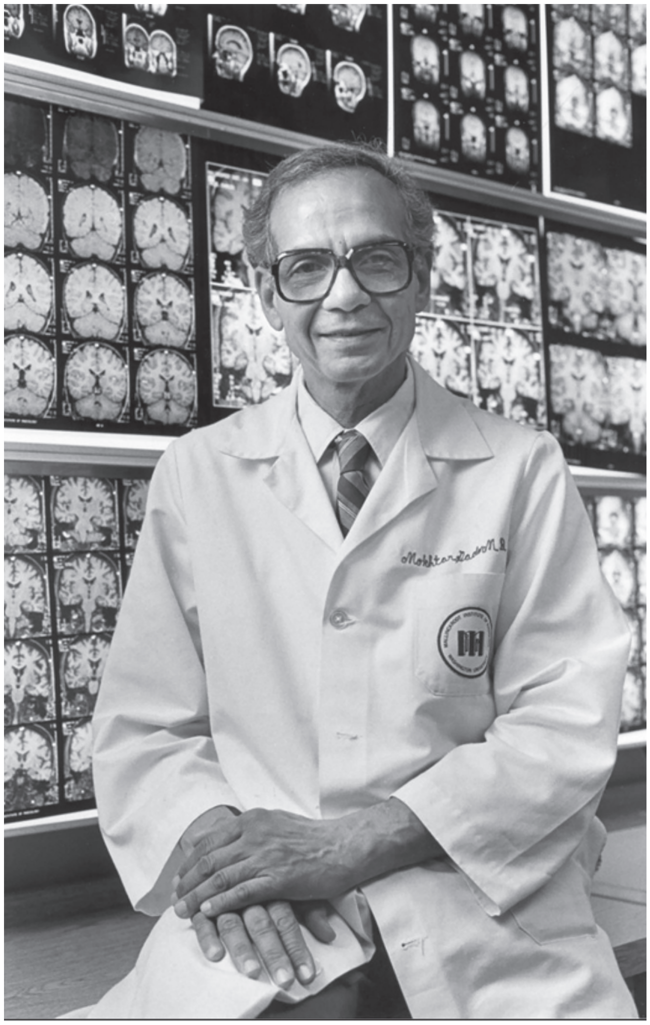
In Memoriam



Neuroradiologist Mokhtar H. Gado, 1992

Mokhtar Gado, c.1992. Courtesy of MRI Photography.

Mokhtar H. Gado, MD, (1933–2016) was a leading researcher, clinician, educator and mentor for decades at the Mallinckrodt Institute of Radiology (MIR) at Washington University School of Medicine in St. Louis.

Dr. Gado's work on the nervous system included: a) Extensive research involving magnetic resonance imaging (MRI) of the brain and spine; b) The radiological manifestations of Alzheimer's disease and brain changes in the elderly; and, c) The correlation of physical principles of magnetic resonance to the pathologic changes in the disease processes of the central nervous system. All had significant impacts in clinical neuroscience.

Dr. Gado was born in Monoufiah, Egypt. He earned his bachelor's degree in 1949 and his medical degree in 1953 at Cairo University. After completing his internship, residencies and fellowships at Cairo University Hospital, he took fellowships at Addenbrooke's Hospital in Cambridge, England and at, what was then, the National Hospital for Nervous Diseases, in Queen Square, London. In 1970, he came to Washington University School of Medicine in St. Louis as a fellow in radiology. In 1971, Dr. Gado was appointed chief of the neuroradiology section which he led until 1991. Thereafter, he continued active research, teaching and scholarship. He was appointed Professor Emeritus in 2013.

FOURTH EDITION

The Brain Atlas

A VISUAL GUIDE TO THE HUMAN CENTRAL NERVOUS SYSTEM

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Registered Office
John Wiley & Sons Ltd, The Atrium, Southern Gate, Chichester, West Sussex, PO19 8SQ, UK

Editorial Offices
9600 Garsington Road, Oxford, OX4 2DQ, UK
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Library of Congress Cataloging-in-Publication Data

Names: Woolsey, Thomas A., 1943– author. | Hanaway, Joseph, 1933– author. |
Gado, Mokhtar H., 1931–2016, author.
Title: The brain atlas : a visual guide to the human central nervous system /
Thomas A. Woolsey, Joseph Hanaway, Mokhtar H. Gado.
Description: Fourth edition. | Chichester, West Sussex, UK ; Hoboken, NJ :
John Wiley & Sons, Inc., 2017. | Includes bibliographical references and index.
Identifiers: LCCN 2016039529| ISBN 9781118438770 (pbk.) | ISBN 9781118438756
(adobe pdf) | ISBN 9781118438763 (epub)
Subjects: | MESH: Brain–anatomy & histology | Central Nervous System–anatomy &
histology | Atlases
Classification: LCC QM455 | NLM WL 17 | DDC 611/.81–dc23
LC record available at https://lccn.loc.gov/2016039529

A catalogue record for this book is available from the British Library.

Wiley also publishes its books in a variety of electronic formats. Some content that appears in print may not be available in electronic books.

Cover image: By courtesy of J/B Woolsey Studios

Set in 11/12.5pt Minion by SPi Global, Pondicherry, India

1 2017

Dedicated to

Clinton N. Woolsey
Jerzy E. Rose
David Bodian
W. Maxwell Cowan
Robert H. Ackerman
Verne S. Caviness
James W. Bull
George du Boulay

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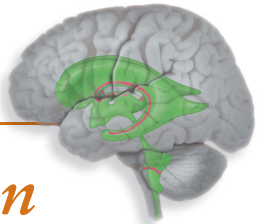

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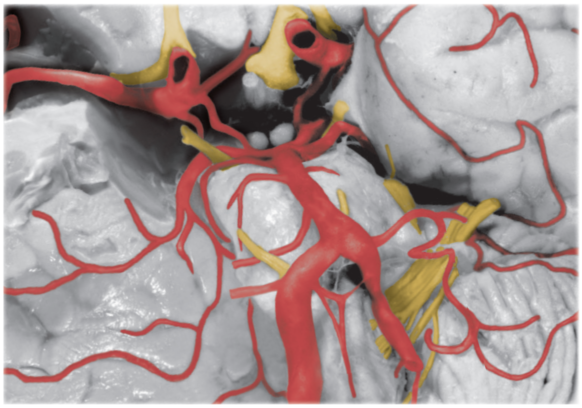

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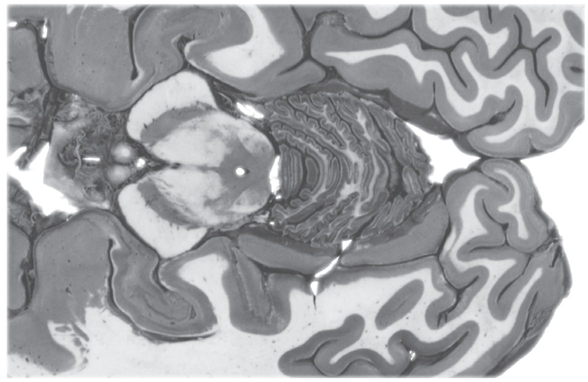

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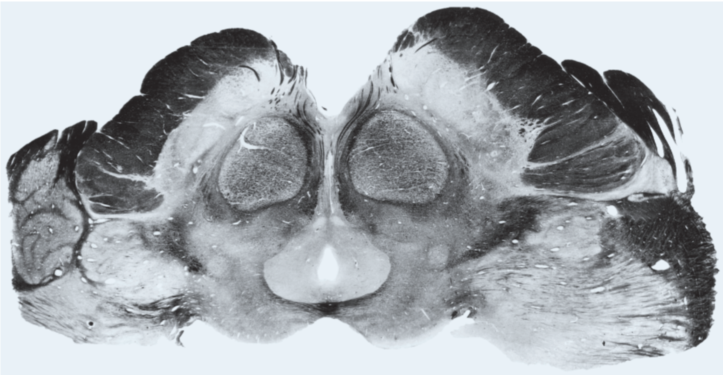

PART V

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Preface

The Fourth Edition of *The Brain Atlas* includes significant updates, additions and modifications:

1. The illustrations of pathways use colored lines to identify different components. The adjacent text now includes colored type to highlight relevant descriptions.
2. Images of brain developmental stages have been added to illustrate Table 1 (p. 10).
3. For a more complete description of mammalian anatomical orientation, terminology labels - frontal and occipital - have been placed next to the human head (p. 13).
4. The section on arousal and sleep has been moved to Hypothalamus (p. 222).
5. Two new sections have been added to Hypothalamus: a) a section describing hypothalamic centers for feeding (p. 228); b) a section describing the Circumventricular Organs (CVO) located near the midline surrounding the third and fourth ventricles. CVOs have no blood brain barriers and are routes by which blood contents can activate neurons throughout the CNS. Some have secretory functions of their own, i.e., the Pineal Gland secretes melatonin calibrating the biological clock of sleep and wakefulness (p. 230).
6. *The Brain Atlas* now also allows users (students, residents, researchers, faculty and practitioners) to interact with a companion digital edition. Your personal access code can be found in the inside front cover or, if you have purchased an e-book, in the prelim pages by contacting customer service as directed. The digital companion includes interactive pages showing dynamically displayed illustrations to enhance learning, such as show/hide functionality ideal for self-test, and the ability to build up nerve pathways. Links allow the reader to navigate the product and see more quickly how slices in one plane relate to slices in other planes. *The Brain Atlas* digital companion can be downloaded to your desktop or used online, and is also accessible with hand held and other mobile electronic devices at any time in any location.

Acknowledgments

The acknowledgment page of any book is a chance for the authors to thank and to give credit to the people 'behind the scenes' who get a technical work like *The Brain Atlas* into print and an application. The authors know how precise labeling areas in the brain must be and we thank the professionals who followed our detailed instructions:

Claire Bonnett, Publisher, who supervised this project and made it easier to complete this work.
Francesca Giovannetti, Production Editor, who handled all the details of labeling images.
And *Deirdre Barry*, Senior Editorial Assistant, who assisted Claire.

Thomas A. Woolsey and Joseph Hanaway

About the Digital Companion

The *Brain Atlas* comes with free access to a **Wiley Digital Companion: Powered by VitalSource** – a digital, interactive version of this book which you own as soon as you download it.

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PART I

PART I is an illustrated overview of *The Brain Atlas*. The main features of the central nervous system and the organization of this book are described. Sources of the specimens and the methods by which they were prepared and photographed are detailed. Key aspects of the various radiological techniques for the images included are outlined. Selected references are listed at the end.

The Brain Atlas: A Visual Guide to the Human Central Nervous System, Fourth Edition. Thomas A. Woolsey, Joseph Hanaway and Mokhtar H. Gado.

Introduction

Overview

The human nervous system is complex and sophisticated. It is the most remarkable system in biology. A major challenge for neuroscience, psychology, medicine, and, indeed, for civilization is to understand the nervous system at the same fundamental levels at which we now understand other organ systems. Early in the 21st century, only 50 years after the discovery of the genetic "alphabet," the complete human genome has been mapped. Likewise, new knowledge about the brain and diseases that afflict the nervous system is exploding. One goal for future work on the human brain is to reach a level of detailed understanding similar to that now possible for the genome.

An anchor in this quest is information about the structure and organization of the central nervous system (CNS). *The Brain Atlas: A Visual Guide to the Human Central Nervous System* was prepared to help students and professionals understand the normal human brain and guide interpretation of clinical and experimental work.

Clear charts and maps of biological structures have been teaching aids from the earliest times. In the biological sciences, the first detailed and illustrated text based on direct observation was the *De Fabrica Humani Corporis* (1543) and its synoptic *Epitome* (1543) by Andreas Vesalius (1514–1564). Those books have been said to "mark the beginning of modern science." Publication of the *Fabrica* also was a major landmark in book publishing. The highly popular *Epitome* was intended as a primer but served very much as a modern day atlas. Such works have evolved and today are used in the same way maps are used to plan travel and understand geographic relationships.

In the mid to late 19th century, instructional programs in universities and medical schools were developed to teach students to make accurate observations from specimens. This skill enables students to generate and retain mental conceptualizations of complex three-dimensional (3D) structures in the body. In part, this was to prepare students to interpret observations that could be made only at the surfaces of living organisms. Experience with these teaching aids was so positive that, even today, instruction at nearly every level now uses charts and atlases to aid the study of gross anatomy, embryology, histology, and neuroscience. Atlases have been developed for a wide range of other related disciplines, such as pathology, radiology, and surgery. These books support varied and flexible learning plans, styles, and objectives. At their best, such works are ready references for efficient recall and lifelong study—rapidly accessible sources of information. *The Brain Atlas* is intended to be such a work: a reference serving different needs for students learning about the human brain and a resource for rapid clarification in self-directed study, in the classroom, in the laboratory, and in the clinic.

Because of recent stunning advances in imaging, the information included in *The Brain Altas* is more crucial than ever for medical practice, human and animal brain research, and certain branches of psychology. For example, strokes (brain attacks) resulting from insufficient blood supply to parts of the CNS are the leading cause of disability in adults and the third leading cause of death in the United States. Intense efforts are now directed at reducing risk and improving therapy for this disease. The quick access to information on the brain and its blood supply in *The Brain Atlas* is crucial for such efforts. Other forms of "brain disease," such as mental illness, dementia, substance abuse, and a host of genetic syndromes, can be investigated and understood only by reference to the detailed organization of the human brain. Alterations in brain function, such as learning difficulties or speech problems, have also now been directly linked to altered brain structures. In the future, access to basic information about brain structure will be even more essential for evaluating patients at risk for specific diseases and for monitoring and assessing the effects of therapeutic interventions.

New imaging and other innovative techniques have spurred a revolution in the study of the way in which the brain works. Functional imaging of healthy individuals at all ages provides a wide range of new and compelling information on how the brain executes different tasks, from speaking different languages to reacting to pain. Such imaging promises to reveal, for example, the ways in which the brains of individuals with special talents may differ. The human brain is no longer a "black box" from which one only rarely and fortuitously records activity. Instead, the precise locations in the brain associated with many uniquely human tasks can be specified. Therefore, ready anatomical reference works are crucial for cognitive psychologists and research scientists.

The Brain Atlas is divided into five parts, with key features summarized at the beginning of each. This introduction (Part I) summarizes several general aspects of the brain to help the novice get started or refresh the knowledge of advanced students and practicing professionals. The balance of this overview outlines terminology used in this volume, as well as special features designed to assist in identification, study, and navigation. Information on the sources and preparation of the anatomical images that appear in this book is provided. The main parts of the volume (Parts II–V) are designed to flow logically and progressively, from overall surface anatomy of the CNS (Part II), through cross-sectional gross anatomy (Part III) and selected regional histology (Part IV), and ending with diagrams of the major neuronal systems that are responsible for the brain's magnificent array of functions (Part V). Because each part illustrates a different aspect of the structure and organization of the CNS, the book is arranged so that users can navigate easily between topics for efficient learning and comprehension.

The Nervous System

Cells

The cells of the nervous system are of two principal types: **nerve cells** or **neurons**, which are directly responsible for conveying and processing information; and **glial cells** (Gr., *glia,* glue), that support the neurons and make them more efficient and effective. Neurons exhibit a wide range of shapes, sizes, functional characteristics, and chemical attributes. Most neurons are not visible without magnification. Neurons differ from all other cells in that they have numerous microscopic processes extending for great distances from the cell body (**soma**; Fig. 1). All neurons are polarized, that is, different parts are specialized to receive or send information. For most nerve cells, these functions are segregated in two different classes of processes. **Dendrites**, shorter processes (~1 mm or less) that are tapered and branched much like limbs on a tree, receive and integrate incoming information. Most neurons have several dendrites. **Axons** (usually only one per neuron) have a relatively uniform diameter, can be highly branched, and extend for considerable distances, up to almost 2 m in tall people. Axons distribute signals to other cells (neurons, muscle cells, secretory cells, etc.) without attenuation. The principal mode of communication between neurons and from neurons to other tissues, such as muscle, is through specialized contacts called **synapses** (Gr., *syn* + *haptein*, clasp). Synapses are small and require magnification under a microscope to be seen. Axons convey information through synapses throughout the brain to activate specific targets.

Gray Matter/White Matter

Different parts of the brain and spinal cord have distinctive appearances. These anatomical distinctions can be correlated almost without exception to specific functional attributes, such as the sense of touch, language understanding, or the ability to execute complex movements such as dancing. Because of the appearance of fresh brain tissue, areas rich in neurons, synapses and glia are called **gray matter**, and areas containing mainly axons and glia are called **white matter** (Figs. 1 and 2). This distinction is

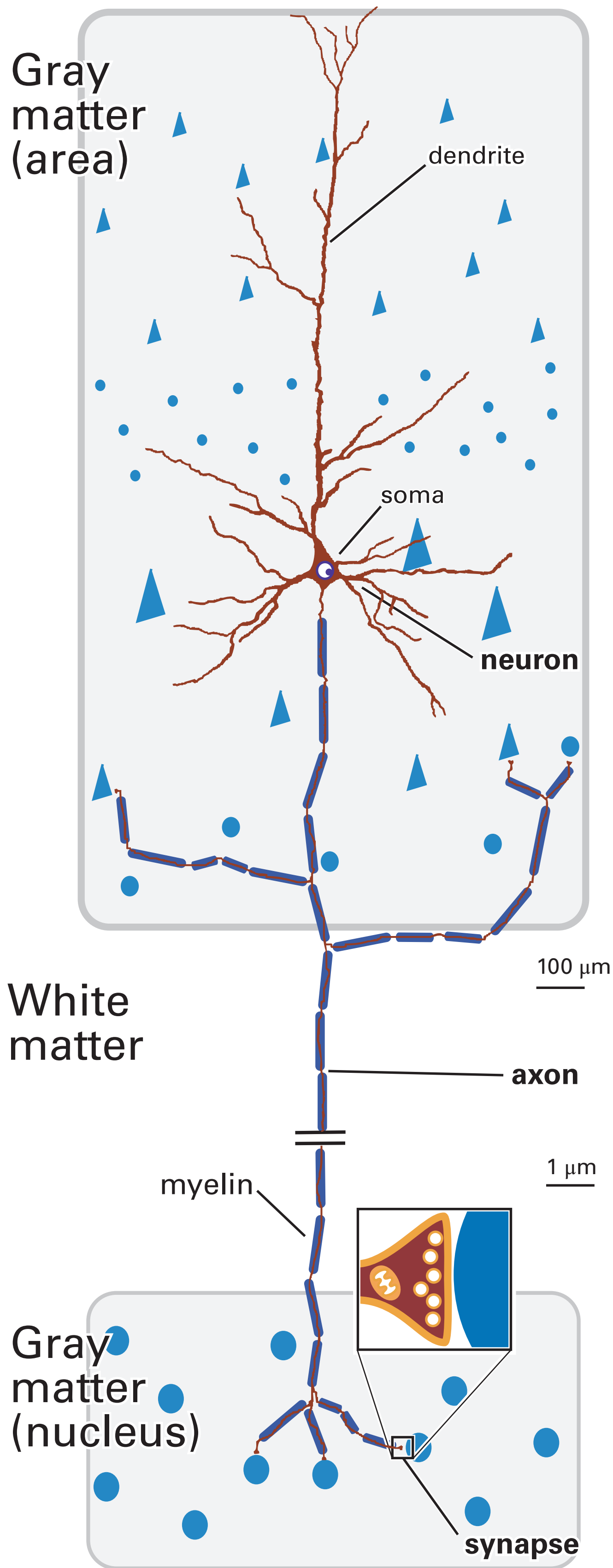


Figure 1 Schematic illustration of major elements of the central nervous system that are sources and targets of connections that facilitate different functions. Gray matter is rich in neurons, connecting axons, and contact points called synapses. For example, a gray matter area, the cerebral cortex, connects to a gray matter nucleus via a myelinated axon of a nerve cell. The full extent of the axon is not shown (//) but could extend for more than 1 m. One synapse is enlarged. Some but not all of the neurons in the gray matter are diagrammed as they would appear with cell body stains (blue circles and triangles; see pp. 165 and 166). Note the scale bars for the gray matter and the enlarged depiction of a synapse. These can be compared with actual images of gray and white matter in Figure 2.

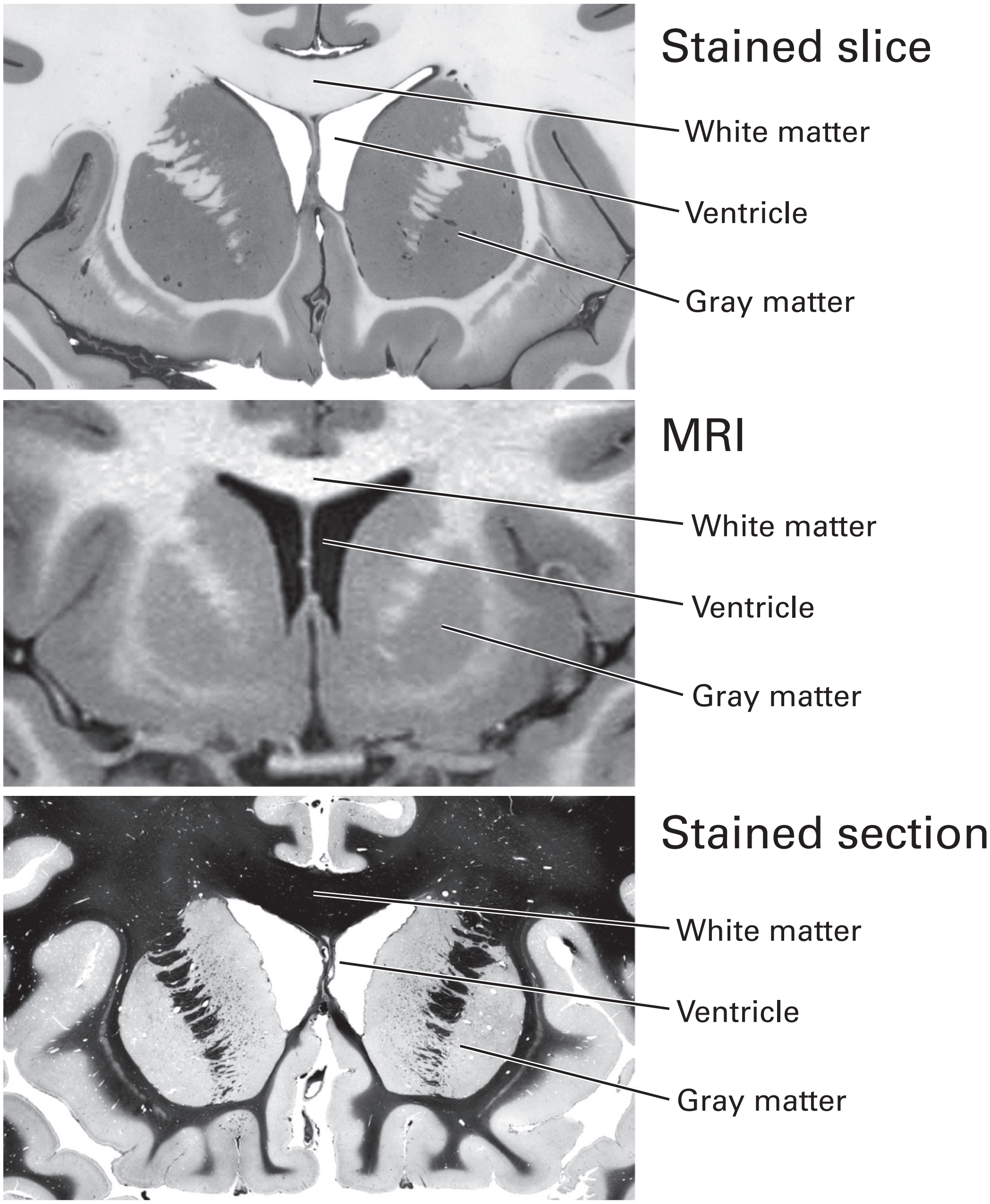


Figure 2 Differences between gray matter (regions that are neuron and synapse rich) and white matter (regions rich in myelinated axons and surrounding glia) are shown with three different methods used to prepare materials for *The Brain Atlas.* All images (from pp. 58, 59, and 155) are in the coronal plane and are reproduced at life size.

useful in understanding anatomical studies from normal or autopsy specimens and, increasingly, from images of living individuals.

Signals are processed within the gray matter by groups of neurons that have similar functions, appearance, inputs, and outputs. Such groups are termed **nuclei** (e.g., hypoglossal nucleus), **areas** (e.g., dorsal tegmentum), or were named because of a fancied resemblance to specific objects (e.g., Gr., *hippokampos*, seahorse = hippocampus). Detailed maps of the locations, identities, connections, and functions of these different gray matter structures are provided in this book.

Longer connections through axons of neurons having similar functions travel and conduct signals from one area to another (for example, from the top of the brain to the bottom of the spinal cord), grouped together as fascicles and/or tracts. Many, but not all, axons are wrapped by **myelin**, the membranes of a specific class of glia (oligodendrocytes), effectively serving as electrical insulation for the axons. Myelin greatly speeds the conduction of impulses along axons while allowing them to be smaller, more densely packed, and much more economical to maintain. In fresh brain tissue, regions of the brain lacking neuronal cell bodies but rich in axons and their myelin covers or sheaths have an ivory/white appearance that differentiates **white matter** from gray matter. *The Brain Atlas* provides a convenient map of the locations, identities, connections, and functions conducted in different white matter structures (Fig. 2). Images of brains prepared or visualized in several standard ways illustrate the different regions of the brain and the characteristics and functional attributes of both gray and white matter.

Connections

Several schemata have been devised to indicate the connections between different neurons and regions of the nervous system. This was originally accomplished with artists' drawings of slices or sections through the brain. Correlations are more direct in this book, because the actual photographic and radiographic images of the external and internal organization of the CNS in Parts II–IV are used to construct diagrams of its pathways in Part V. The convention shown in Figure 3 represents a group of neuron cell bodies (without dendrites) and synapses they make with other cells in and out of the CNS. In such diagrams, the direction of information transfer always goes away from the neuron cell body (•), along its axon to the synapse (-<), and then to the next cell body, axon and synapse to complete the neural pathway. Part V depicts pathways in the diagrams and summarizes them in the accompanying text.

CNS/PNS

The nervous system has two main divisions: the CNS and the peripheral nervous system (PNS). This book focuses on the CNS (Fig. 4), those parts of the nervous system that are protected in the cranial cavity of the skull and in the spinal canal formed by the vertebrae and their neural arches. The PNS consists of spinal and cranial nerves, collections of neurons (ganglia), and neurons scattered in different organs of the body, such as the gut, heart, and urinary bladder.

Constitution of the CNS

The adult brain weighs between 1250 and 1450 g and occupies ~1400 cc. The adult spinal cord is approximately 50 cm long and occupies ~150 cc. The weight of the CNS therefore constitutes nearly 3% of the total body weight of a 50-kg woman and slightly more than 2% of that of a 70-kg man. In spite of its relatively small size, the brain receives

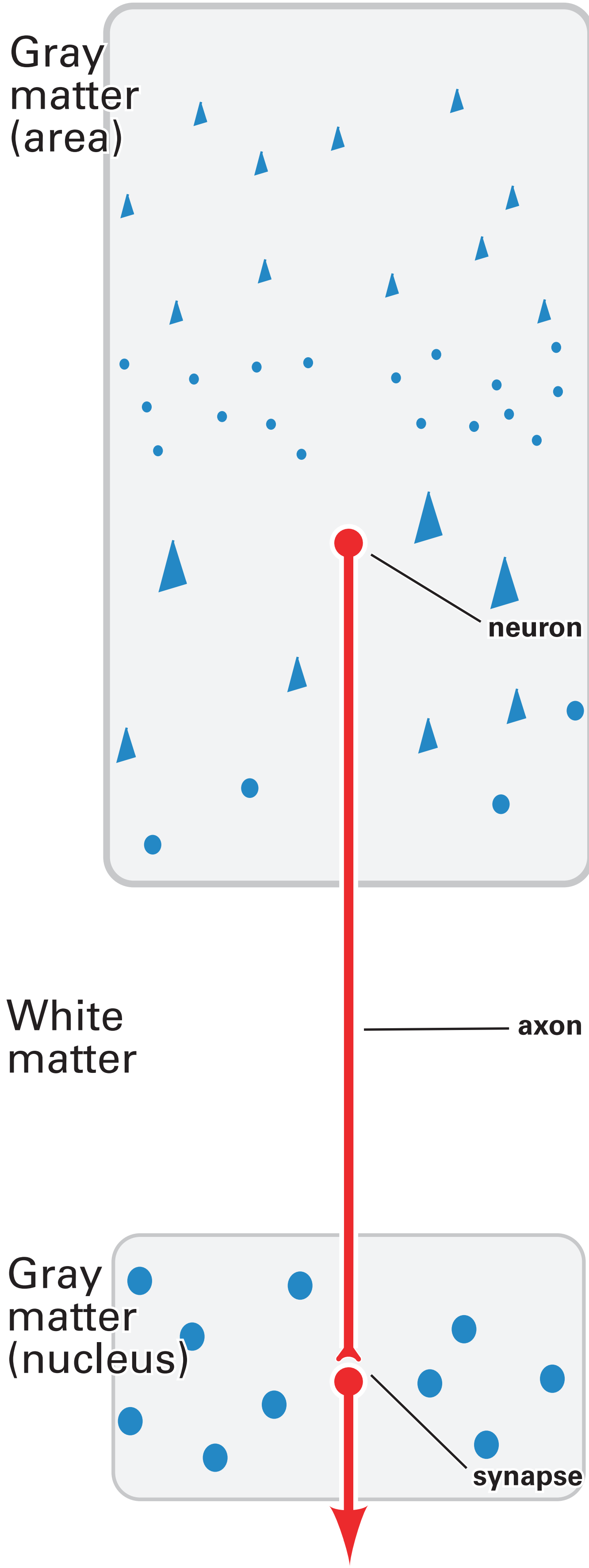


Figure 3 The red shows the conventions based on the sketch in Figure 1 used to illustrate brain pathways in Part V (Fig. 11). Solid circles represent neurons and their dendrites; colored lines represent the course of the axons; and the "Y" represents presynaptic endings on neurons in the target nucleus. Arrowheads indicate projections to distant targets not illustrated directly.

about 15% of the output of the heart, utilizes about 20% of the body's oxygen, and metabolizes a similar percentage of body glucose, regardless of whether an individual is alert or sleeping. Its upkeep is therefore expensive. Half of all human genes (currently estimated at 20,000) are expressed uniquely in the nervous system; of the remaining half, 70% are expressed in the brain as well as elsewhere in the body. It has been estimated that the CNS contains about 100 billion neurons that make more synaptic connections in each individual than the number of stars, planets, and all other known objects in the universe. Neurons, their processes, and the synapses they make are supported by approximately a trillion glial cells.

Principal Divisions of the Brain

In early development, the brain and spinal cord arise from the neural tube, which greatly expands in the front end of the embryo to form the main divisions of the brain (Fig. 5, Table 1). The adult brain consists of: the **telencephalon**, which includes the cerebral cortex, basal ganglia, and olfactory bulbs; the **diencephalon**, which includes the thalamus, hypothalamus, and epithalamus; the **mesencephalon** or midbrain, which includes structures around the cerebral aqueduct, the superior and inferior colliculi, and the cerebral peduncles; the **metencephalon**, which includes the pons and cerebellum; and the **myelencephalon**, which includes the open and closed medulla.

Cranial Nerves and Spinal Segments

This book focuses on the brain and the organization of connections within it. Communication between the brain and the outside world (such as that occurring while reading this book) depends on connections between the brain and the PNS, either directly through the 12 pairs of **cranial nerves** numbered I–XII (CN I–CN XII) or from the spinal cord via 31 pairs of spinal nerves. The cranial nerves traverse openings in the skull (principally foramina) while the spinal nerves exit between adjacent vertebrae.

The spinal cord and spinal roots are organized segmentally. The different segments of the spinal cord and related **segmental spinal nerves** connecting it with the periphery are pertinent to understanding the organization of specific neural pathways. Spinal segments are defined by their proximity to specific bones that form the spinal column. The spinal column consists of 33 vertebrae: 7 in the neck (cervical, C1–C7), 12 in the thorax (T1–T12), 5 in the abdomen (lumbar, L1–L5), 5 in the pelvis (sacral, S1–S5), and 4 in the diminutive "tail" (coccygeal, Co1–Co4). The spinal cord lies within the bony spinal canal of the spinal column and consists of 31 segments: 8 cervical (neck), 12 thoracic (chest), 5 lumbar (back), 5 sacral (pelvis), and 1 coccygeal ("tail"), each giving rise to a pair (right and left) of spinal nerves (C1, T1, L1, S1, Co1, etc.) (Fig. 4).

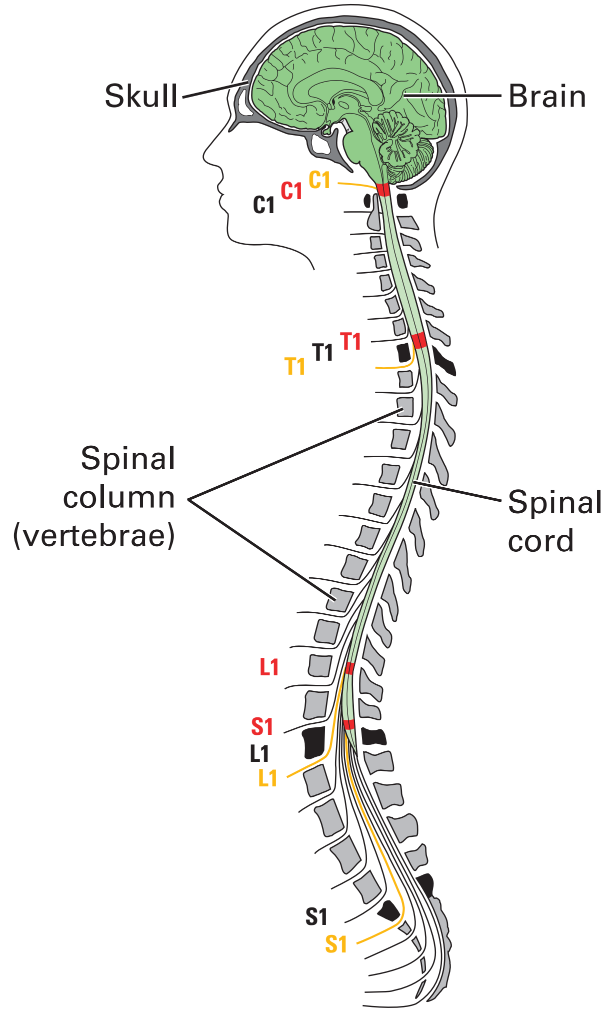


Figure 4 Schematic drawing of the central nervous system (CNS) in the midsagittal plane. The CNS is within skeletal elements. The brain (darker green) is surrounded by the skull (darker gray), and the spinal cord (lighter green) is surrounded by 33 vertebrae that make up the spinal (vertebral) column. The spinal cord is divided into segments in relation to the labeled vertebrae (black; C1, T1, etc.). The spinal nerves (yellow) course between and are labeled in relation to the vertebrae (C1, T1, etc.). The intersection of the spinal nerves with the spinal cord defines the segment (red) of the spinal cord (C1, T1, etc.). Some spinal nerves have an extended intraspinal course from their (superior) spinal segment before exiting below a vertebra (compare S1 with T1).

Each pair of spinal nerves exits the spinal canal between two adjacent vertebrae, except superiorly (above), where the first pair exits between the skull and C1. Each cervical root is numbered by the vertebra *below* its exit. The lowest cervical nerve, C8, exits between vertebrae C7 and T1. Below C8, each spinal nerve, including T1, is labeled with the same number as the vertebra *above* its point of exit. The spinal nerves define segments of the spinal cord. In the upper cervical region, a spinal cord segment lies at approximately the same level as the corresponding vertebra. Inferiorly (or below), spinal cord segments lie at progressively more superior levels than the corresponding vertebrae. The adult spinal cord ends at the level of the first lumbar vertebra (L1). The discrepancy between the cord

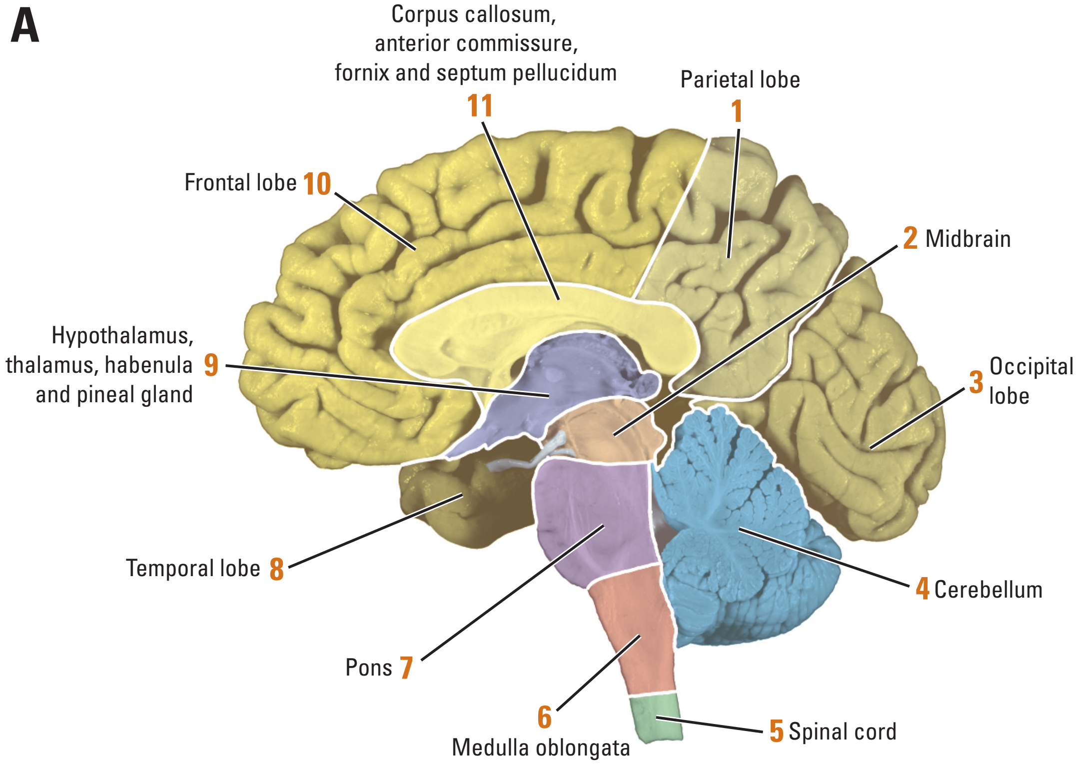
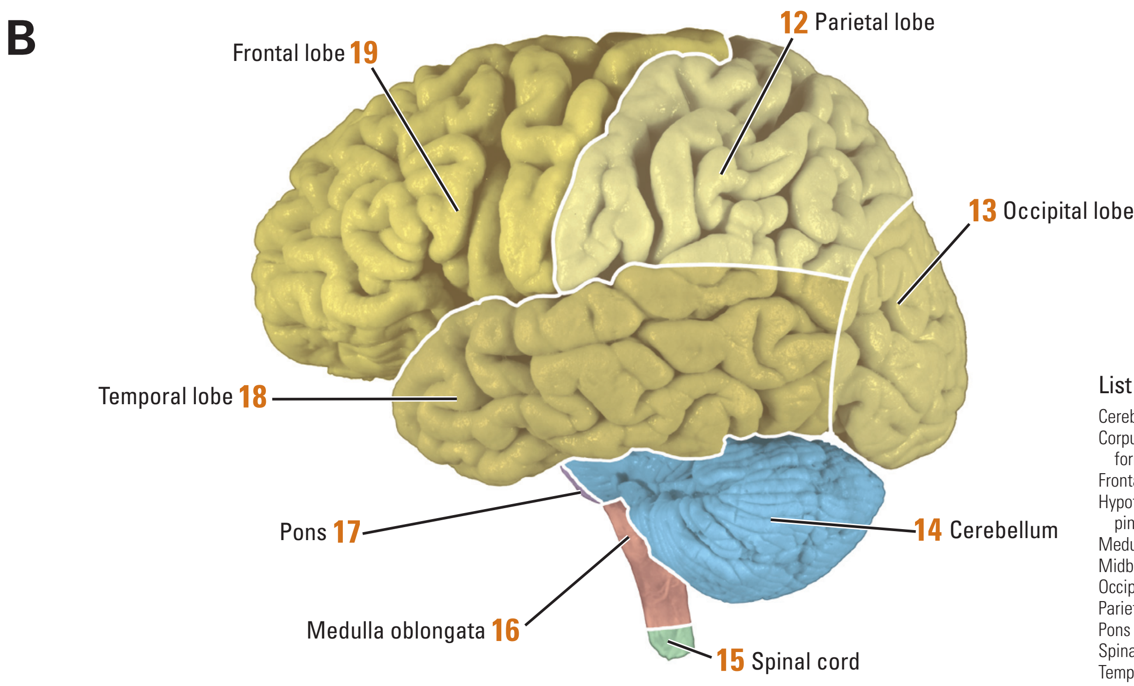


Figure 5 The main divisions of the brain and lobes of the cerebral cortex are colored and labeled in midsagittal **A** and lateral **B** views of the brain from images in Part II (0.6X). The relation of these divisions to the brain stem and cerebrum are summarized in Table 1. The table also indicates the embryonic origins of the different parts of the central nervous system to which many of these divisions correspond.



List for A and B

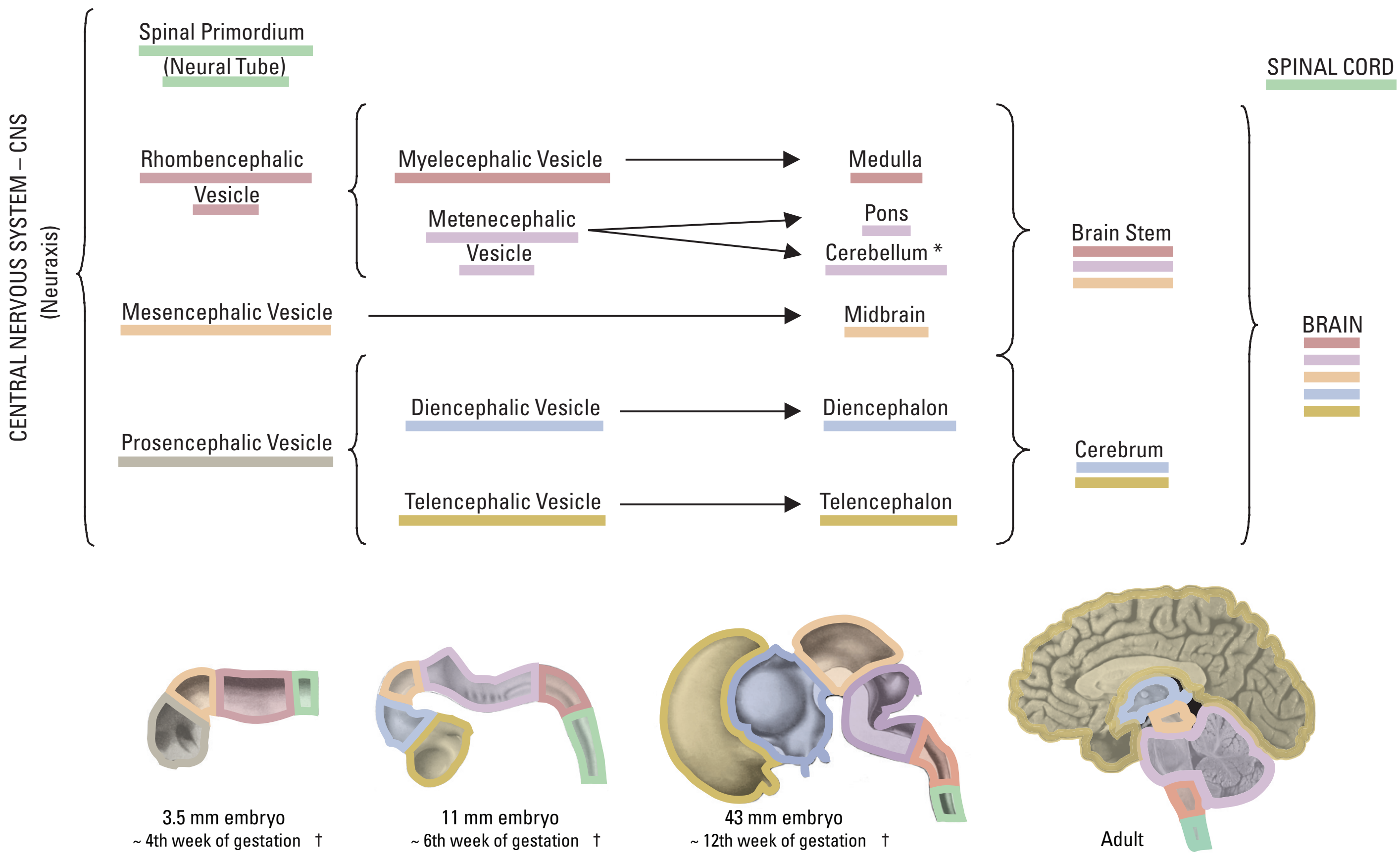
Cerebellum 4, 14
Corpus callosum, anterior commissure, fornix and septum pellucidum 11
Frontal lobe 10, 19
Hypothalamus, thalamus, habenula and pineal gland (diencephalon) 9
Medulla oblongata (myelencephalon) 6, 16
Midbrain (mesencephalon) 2
Occipital lobe 3, 13
Parietal lobe 1, 12
Pons 7, 17
Spinal cord 5, 15
Temporal lobe 8, 18

and vertebral levels is a result of differences in the growth of the spine and spinal cord. Below L1, nerve roots occupy the spinal canal, where they constitute the cauda equina ("horse tail").

Cerebrospinal Fluid and Its Circulation

The lumen (hollow center) of the embryonic neural tube persists in the fully formed spinal cord and closed medulla as the central canal. In the rest of the brain, it expands with the **cerebral** vesicles into the ventricular system. The brain and spinal cord are filled and bathed by ~150 cc **cerebrospinal fluid** (CSF), which fills the ventricles, the central canal, and the subarachnoid space between the pia on the brain surface and the arachnoidal membrane just deep to the dura. Widened regions of the subarachnoid space are called cisterns. The choroid plexus, a specialized secretory epithelium found in each

Table 1. Ontogenesis of the CNS



* The cerebellum is considered part of the brain stem, although it is technically a separate structure.

† After Hines.

ventricle (Fig. 6A and 6B), actively generates CSF that continuously bathes and cushions the brain. The ~700 cc CSF secreted per day (4+ fresh baths every 24 hours) circulates from the ventricles, exiting below the cerebellum and through the subarachnoid space, eventually draining into the venous system.

Cortical Areas

In this volume, descriptive anatomical names are used for structures depicted at different levels of resolution. However, a widely accepted system of numbering the different regions of the well-developed human cerebral cortex is frequently used also. These regions were defined based on microscopic patterns of nerve cell bodies (cytoarchitectonics) or myelin (myeloarchitectonics). The most widely used of these is based on numbers published by Korbinian Brodmann (1868–1918) in 1909. This system divides the mammalian cortex into “Brodmann’s areas” (indicated in Fig. 7A and 7B by circled numbers), many of which correspond surprisingly closely to known, separable, brain functions and to patterns of connections.

Using this Book

Terminology

Correct names and terms for structures in the brain are essential for clear communication but are constantly changing as more is learned about the brain. Use of terms based on the spoken language of students and faculty is a worldwide trend that has been recognized by the International Federation of Associations of Anatomists (IFAA). The latest revised terminology, *Terminologia Anatomica* (referred to here as *Terminologia)*, is used in *The Brain Atlas*. Terms are provided in English (for example, part for pars) or as taken from the older Latin, Greek, and Egyptian terms of anatomy and medicine that are now part of the English language (for example, substantia nigra—black substance). Because not everyone has adopted the *Terminologia* terms, this book provides the common usage followed by the *Terminologia* equivalent, for example, gyrus rectus (straight gyrus). Common synonyms and eponyms are also used: corticospinal (pyramidal) tract; basal vein (basal vein of *Rosenthal*).

To identify structures consisting of several parts, the principal structure is followed by the specific part(s),

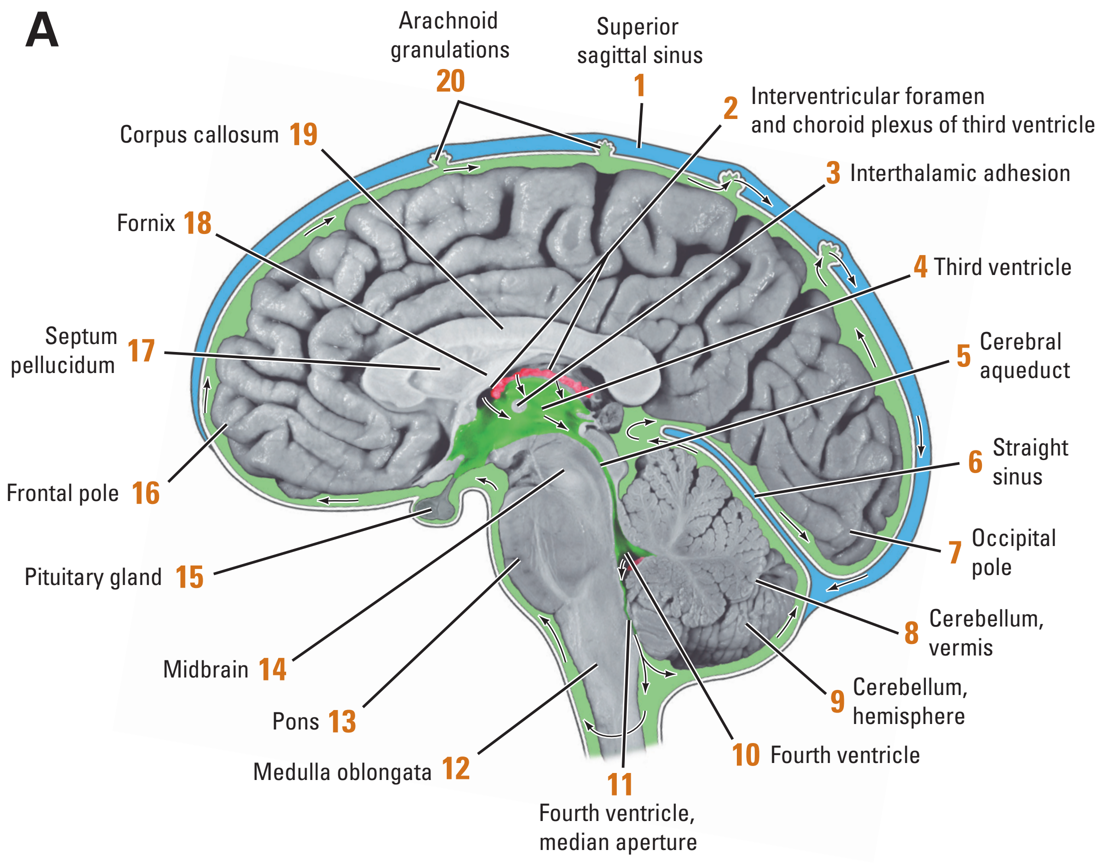
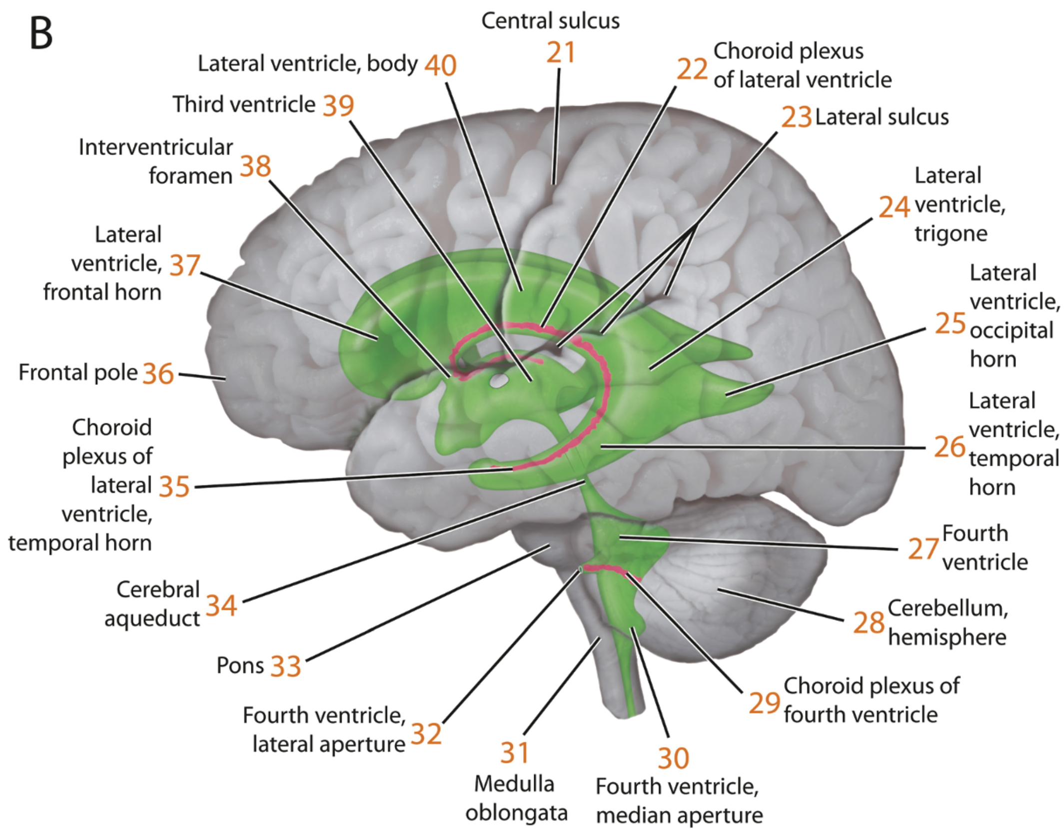


Figure 6 Midsagittal **A** and lateral **B** views of the brain from Part II are the basis for these schematics (0.6X). The brain is bathed in cerebrospinal fluid (CSF) that is continuously produced, circulated, and absorbed. The location of the choroid plexus (red), which makes CSF, is shown in all four brain ventricles. The CSF (green) circulates through the ventricular system and over the brain in the direction shown by the arrows. It ultimately returns to the venous system (blue). In the head, this transfer is through special structures, the arachnoid granulations.



List for A and B

Arachnoid granulations **20**
Central sulcus (fissure of ***Rolando***) **21**
Cerebellum, hemisphere **9, 28**
Cerebellum, vermis **8**
Cerebral aqueduct (aqueduct of ***Sylvius***) **5, 34**
Choroid plexus of fourth ventricle (IV) **29**
Choroid plexus of lateral ventricle **22**
Choroid plexus of lateral ventricle, temporal (inferior) horn **35**
Corpus callosum **19**
Fornix **18**
Fourth ventricle (IV) **10, 27**
Fourth ventricle (IV), lateral aperture (foramen of ***Luschka***) **32**
Fourth ventricle (IV), median aperture (foramen of ***Magendie***) **11, 30**
Frontal pole **16, 36**
Interthalamic adhesion (massa intermedia) **3**
Interventricular foramen (foramen of ***Monro***) **2, 38**
Lateral sulcus (***Sylvian*** fissure) **23**
Lateral ventricle, body **40**
Lateral ventricle, frontal (anterior) horn **37**
Lateral ventricle, occipital (posterior) horn **25**
Lateral ventricle, temporal (inferior) horn **26**
Lateral ventricle, trigone (atrium) **24**
Medulla oblongata **12, 31**
Midbrain **14**
Occipital pole **7**
Pituitary gland **15**
Pons **13, 33**
Septum pellucidum **17**
Straight sinus **6**
Superior sagittal sinus **1**
Third ventricle (III) **4, 39**

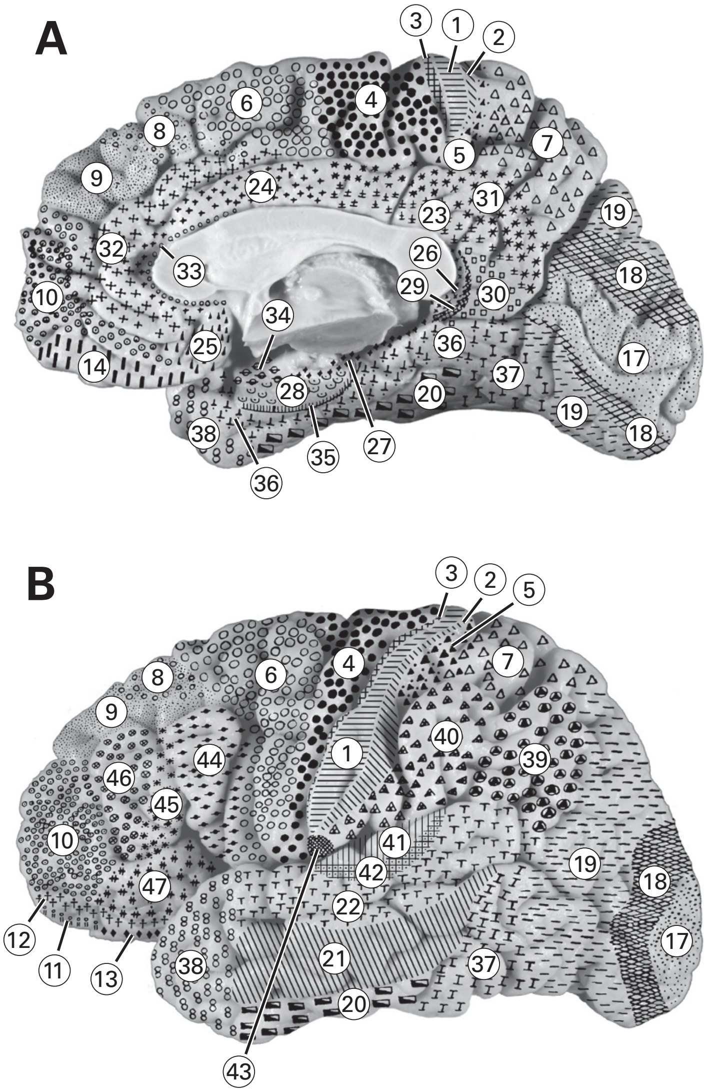


Figure 7 Areas of the cerebral cortex differ consistently in their microscopic structure. The structural differences reflect, in part, connections within an area and to and from other parts of the central nervous system. Brodmann's system of numbers identifies different cortical areas. These have been transposed to the midsagittal **A** and lateral **B** views on specimens depicted in Part II. Numbered areas have frequently been shown to correspond to known functions. Notable examples are area 4 for control of fine movements, area 41 for audition, and area 17 for vision. This and other similar systems of identification are widely used, especially when a specific functional/connectional correlation has been established for an area of the cerebral cortex.

separated by a comma: hippocampus, CA3, pyramidal layer; thalamus, centromedian nucleus (CM); fourth ventricle (IV), median aperture (foramen of *Magendie*). Terms for nuclei in the thalamus include an abbreviation in parentheses: centromedian nucleus (CM); ventral posteromedial nucleus (VPMm), medial part; thalamus, pulvinar (Pul). Cranial nerves and associated structures are numbered with capital Roman numerals: vagal (CN X) trigone; trigeminal (CN V); abducent nucleus (CN VI). The third and fourth ventricles are indicated with capital Roman numerals: fourth ventricle (IV).

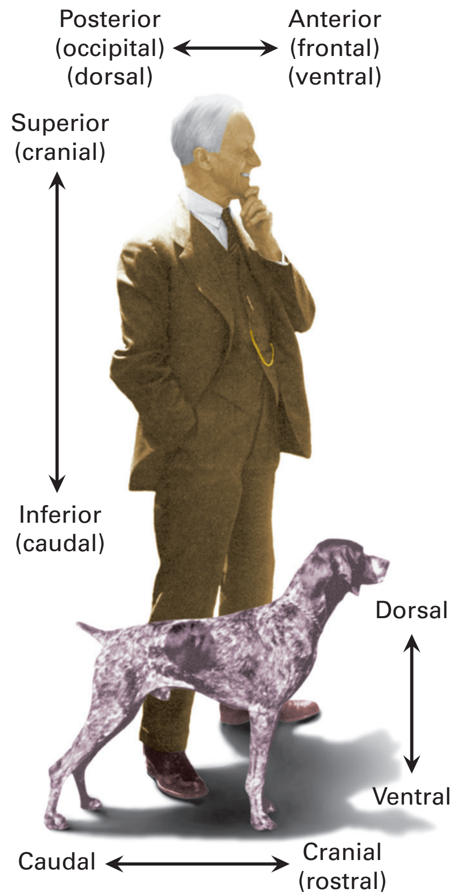
Terms of Relation—The Special Case of the Human Head

Adjectives describing anatomical relations are thoroughly discussed in textbooks of anatomy. Here, adjectives from the *Terminologia* are used, but commonly used synonyms that describe position or relation are included in parentheses: posterior (dorsal) horn; anterior (ventral) cochlear nucleus (CN VIII). In particular, terms of comparison related to humans (bipeds) and four-legged animals (quadrupeds) (Fig. 8) are confounded because in humans and other primates, the axis of the forebrain and skull is at nearly 90° to the axis of the spinal cord and body. This is in contrast to the dog and other commonly studied animals where the axis of the forebrain and skull is the same as the axis of the spinal cord and body (Fig. 8). Accordingly, homologous structures in the brains of humans versus cats and dogs can have different relations to the principal body axes. For instance, structures within the human brain that are nearer to the back of the head are often named posterior (dorsal) with respect to the principal body axis. An example is the occipital (posterior) horn of the human lateral ventricle. In dogs, however, the same structure is oriented toward the tail (caudal) rather than to the back (dorsal). The coronal plane of section (paralleling the coronal suture of the skull) is across the skull in both humans and dogs. In dogs this plane is perpendicular to the long axis of the body crossing from dorsal (posterior) to ventral (anterior); in people it is parallel to the long axis of the body from superior to inferior (Fig. 8). In the *Terminologia* this distinction is now made clearer. For instance, in the *Terminologia*, pontine reticular formation, superior part, is preferred over the traditional usage, rostral reticular formation. In *The Brain Atlas,* lists give the preferred term with the synonym in parentheses: anterior (ventral) horn; posterior (dorsal) spinocerebellar tract. In some instances, the use of quadruped terms of relation, unfortunately, cannot be avoided: *dorsal* supraoptic commissure—not *superior*.

Labels

Structures in *The Brain Atlas* are indicated by leaders (numbered tags), for precise identification of features. These are arranged vertically top down or clockwise, beginning at the top of the image (12 (24) o'clock). The colored numbers are accompanied by the short version of the term identifying the item (for example, median aperture). All terms are listed in full (for example, median aperture [foramen of *Magendie*]) and in alphabetical order and hierarchically (for example Globus pallidus, internal (medial) segment (GPi)) on the same or facing page opposite the labeled image followed by the appropriate number(s) in color. After looking up the structures in the index, the entry can be found in the list of terms and then located by its number around the "clock face." The system offers two options: tracing the leader from a structure to

Figure 8 Terms of comparison as applied to a human (biped) and a dog (quadruped). For the human brain, superior and inferior are preferred in many instances to dorsal and ventral. Although corresponding to structures that are dorsal in quadrupeds, the potential confusion in describing structures in the human head that is at right angles rather than parallel to the long axis of the body complicates clear communications about anatomy. Image taken from a photograph of Harvey Cushing, MD (1869–1939) who was a pioneer in American brain surgery and was particularly interested in the work of Andreas Vesalius. (Reproduced with permission from the American Association of Neurological Surgeons. *A Bibliography of the Writings of Harvey Cushing*, Third Edition, Revised 1993.)



identify it quickly; or from the index to the list on the page from which the pointer(s) is identified by number without an extensive search of the image to find a specific symbol, abbreviation, or other term against the background of a structure (Fig. 9). When several illustrations are grouped on a page, term 1 is related to the image nearest the top of the page. Because of the number of items on each page, all are not labeled in every picture. In particular, larger structures (for example, caudate nucleus, lateral ventricle) that appear in adjacent sections have been labeled on alternate plates. Students are encouraged to try to identify unlabeled structures for self-testing.

Image Groups

The images in each section of *The Brain Altas* are grouped together to facilitate correlation of different classes of information from different sources. For example, images of the brain and its blood vessels are juxtaposed directly with those mapping vascular territories and those

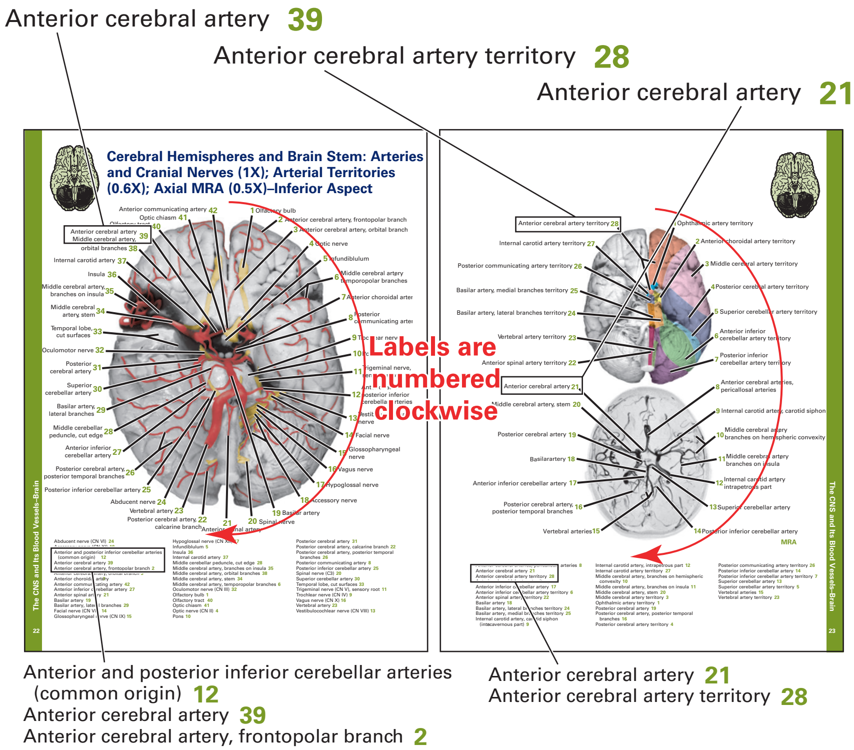


Figure 9 Leaders point to structures identified by the “short” version of the term. Terms are numbered sequentially in color, starting at 12 (24) o’clock. Depending on the exact layout, terms are numbered in sequence around more than one object as shown for the right-hand page here or circling individual objects on a page starting with the object nearest the top of the page. Terms are enlarged at the top of this figure. Each is listed alphabetically in full, usually on the same page (bottom of this figure). Occasionally, the lists are on the facing page or a fold out (see pp. 38–39).