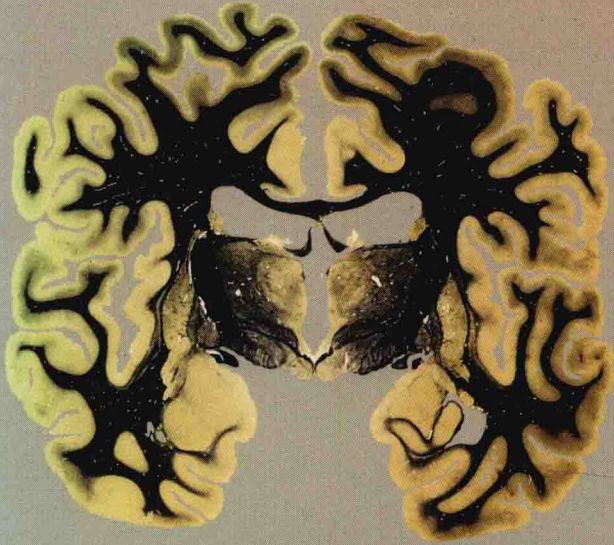


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# THE HUMAN BRAIN

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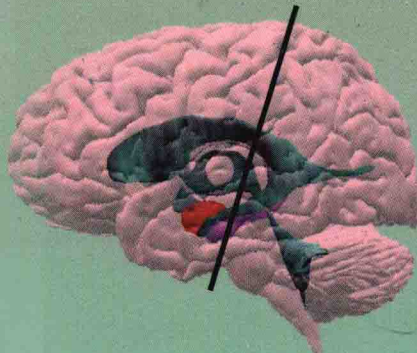


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In Photographs  
and Diagrams

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John Nolte  
Jay B. Angevine, Jr.



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# THE HUMAN BRAIN

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## In Photographs and Diagrams

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## To Our Students

whose enthusiasm maintains ours,  
whose questions prod us to seek clarity and accuracy,  
whose caring and curiosity make teaching fun;

and

## To Paul Ivan Yakovlev

whose wisdom and foresight,  
dignity, kindness and generosity,  
reverence for patients and joy in people,  
enormous energy and personal youthfulness  
created a world library of human and animal brains  
and a world community of neurological scholars.

## PREFACE

Learning about the functional anatomy of the human central nervous system is usually a daunting task. Structures that interdigitate and overlap in three dimensions contribute to the difficulty, as does a long list of intimidating names, many with origins in descriptive terminology derived from Latin and Greek. We have attempted in this book to make the task a little easier for students of the biological and health sciences, by presenting systematic series of whole-brain sections in three different sets of planes, by relating these sections to three-dimensional reconstructions, and by trying to restrain ourselves when indicating structures.

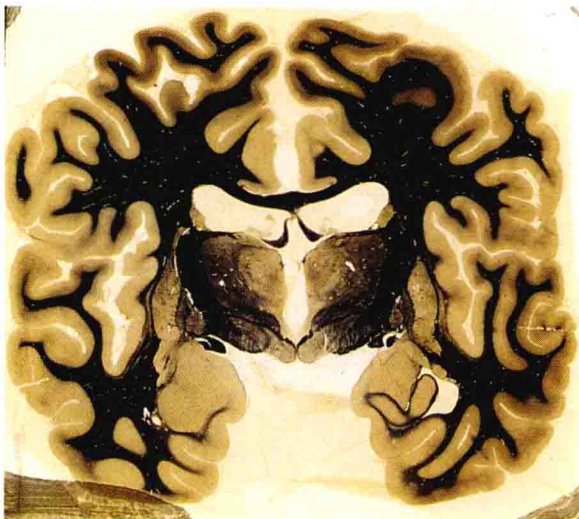
We made a number of choices in organizing the materials for this atlas, and in each instance strove for simplicity. Unlabeled photographs are presented throughout the book, juxtaposed to faded-out versions of the same photographs with important structures outlined and labeled. This circumvents the common need to mentally superimpose a labeled drawing on a photograph. We pored over many hundreds of sections, and chose what we felt to be comprehensive yet not excessive sets in each plane; sections illustrating major structures or major transitions are shown in color and at a higher magnification. Every labeled structure is discussed briefly in a glossary at the end of the book.

These methods inevitably involve compromises. We labeled only structures that we felt important for the knowledge base of undergraduate and professional students, and omitted others dear to our hearts but perhaps not critical for these students. Hence the indusium griseum, the paratenial nucleus and the nucleus of Roller are not indicated. In addition, explicitly outlining structures required some simplifications, and complex entities are sometimes indicated more simply as single structures. We think the resulting utility for students justifies these pedagogical liberties.

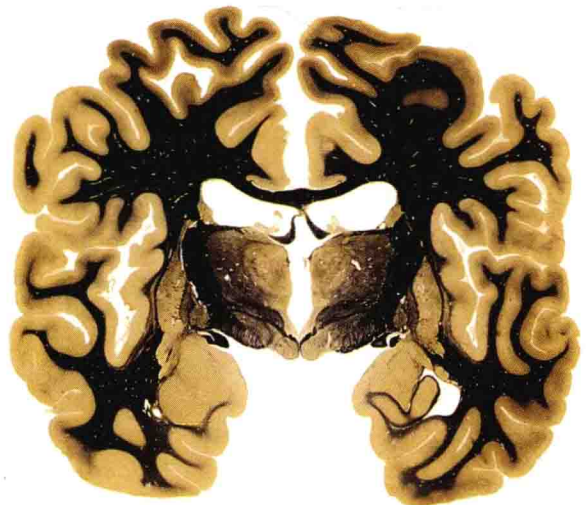
New technological methods allowed us to approach the construction of this atlas differently than we could have just a few years ago. All the photographs of brains and sections used in the book were digitized and then retouched digitally. Mounting medium, staining artifacts, and small cracks, folds and scratches were removed from the digitized versions of the sections. The profiles of many small blood vessels were removed as well. The color balance was changed as appropriate to make the sections as uniform as possible. While not changing the essential content of the images, these procedures improved them aesthetically. In addition, computer-based surface-reconstruction algorithms made possible the beautiful three-dimensional images that appear in Chapter 4 and elsewhere in the book.

**Acknowledgements.** This book could never have happened without the help of many friends and colleagues. Nathan Nitzky's photographic expertise is evident throughout the book. Grant Dahmer prepared the prosecutions shown in Chapter 1. The sections shown in Chapter 2 were cut by Shelley Rowley and those in Chapter 3 by Pam Eller (who has been an important friend and professional colleague of one of us (JN) for decades). John Sundsten produced the three-dimensional images shown in Chapter 4 and elsewhere in the book, and shared in our excitement about this project. Paul Yakovlev, as detailed shortly, was the central figure in the production of the sections shown in Chapters 5-7. Drs. Ray Carmody, Art Gmitro, Robert Handy and Joe Seeger provided the images shown in Chapter 9 and helped with their interpretation. Sasha Zill first described the strumous. Carol and Midge cheered us on. We thank them all.

John Nolte and Jay B. Angevine, Jr.  
Tucson, Arizona  
October, 1994



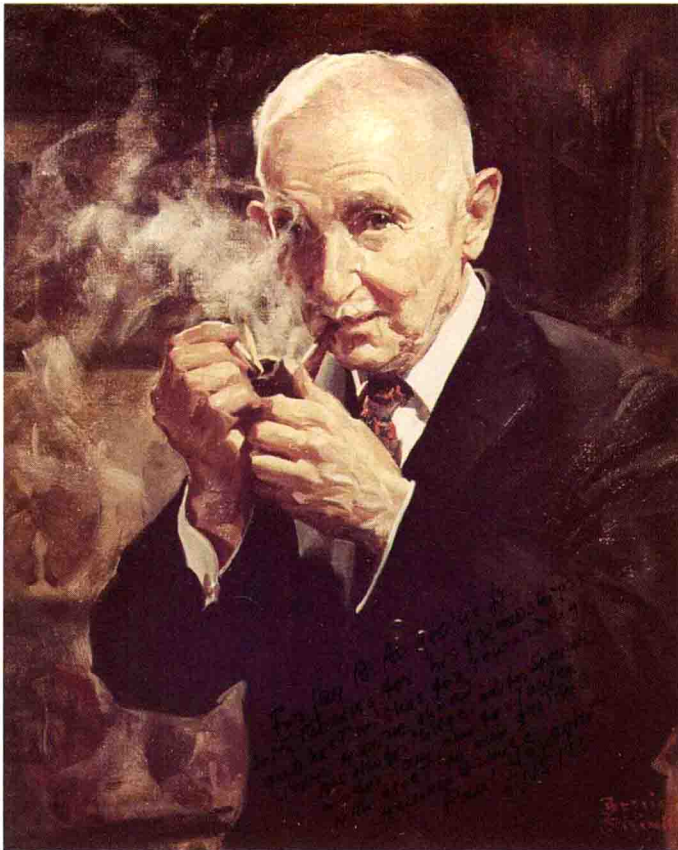
The section shown in Figure 5-6, before retouching.



The section shown in Figure 5-6, retouched.

## A NOTE ON THE WHOLE BRAIN SERIAL SECTIONS AND THEIR ORIGIN

As crucial as computer technology is to our book, the whole-brain serial sections are its foundation. They were prepared during 1966–67 in the Warren Anatomical Museum at Harvard Medical School. The work, in which I took part, was performed under the direction of Dr. Paul I. Yakovlev (1894–1983), Curator of the Museum from 1955–61, then Emeritus Clinical Professor of Neuropathology until 1969. Each brain, embedded whole in celloidin, was sectioned in coronal, horizontal or sagittal planes on a giant microtome with a standing oblique 36-inch blade and a sliding brain holder. The sections, each 35 micrometers thick, were rolled and stored in test tubes in a console of 100 numbered receptacles. After processing pilot sections for suitability and quality, we stained every 20th section with Weigert's hematoxylin (Loyez method) for myelin and mounted it in window glass. Each preparation is thus about 4 mm thick, yet great depth and detail of cells and fibers are visible in it.



Paul I. Yakovlev, M.D.  
1894–1983

An autographed copy of an oil portrait of Paul Yakovlev by Bettina Steinke. The original portrait was presented to the Warren Anatomical Museum at Harvard Medical School in 1978 and now hangs in the Francis A. Countway Library of Medicine, Boston, Massachusetts. (Reproduced with thanks to Richard J. Wolfe, Curator of Rare Books and permission of the Boston Medical Library.)

Such preparations illustrate the white matter and tracts of the brain by staining the myelin sheaths of axons black; gray matter and nuclei appear as more or less pale areas, depending on the number and caliber of myelinated fibers present. The above sections, all from essentially normal brains, were added to an already huge collection representing over 900 cerebra that Dr. Yakovlev had been building since 1930. This priceless compilation is now a national resource known and available to neurological scholars worldwide: the Yakovlev Collection, graciously housed by the Armed Forces Institute of Pathology in Washington, DC. Today. It comprises about 1600 specimens, normal and pathological, processed in a rigorously consistent manner from the start.

In mid-1967, with Dr. Yakovlev's blessing, I took with me to The University of Arizona some 1000 of the 8741 sections cut from the three normal brains used in Chapters 5–7 of this book. I had left Boston to join the faculty of the University's new College of Medicine in Tucson. Paul, my mentor from the time I came to Harvard in 1956, wanted to support me as I began teaching in a far-off land which he believed (perhaps correctly) to be a frontier: the "Wild West." As with everything else he did, it was thoughtful, kind and generous. How he would have loved to see you studying the sections illustrated on these pages! And what, were he standing beside you, would he teach you!

Unlike the fairly simple task of sectioning the brainstem, cutting perfect gapless whole-brain serial sections is difficult. The procedure was never more carefully undertaken or widely employed than by Paul, who used it at or in association with Harvard Medical School for forty years. A central theme for him was this holistic method ("every part of the brain is there, nothing is left out..."), but no aspect of neuroanatomy or neuropathology failed to intrigue him. While such sections had been made since the late 19th century (they are found in small numbers at many medical schools and in profusion at a few research institutes), Paul's are unique—in uniformity of preparation at every step from fixation to mounting, in unity of general neurological interest and comparability. Of his legacy (he called it "over 40 tons of glass"), Derek Denny-Brown, Emeritus Professor of Neurology at Harvard, wrote in 1972: "The perspective given by serial whole brain sections provides at once an arresting view of anatomical relationships in patterns of striking beauty. After working in the collection for years one still finds every occasion to view it illuminating and rewarding."

Jay B. Angevine, Jr.

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# THE HUMAN BRAIN

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In Photographs and Diagrams

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# 1 External Anatomy of the Brain

This atlas emphasizes views of the interior of the human central nervous system (CNS), sectioned in various planes. This first chapter lays some of the groundwork for understanding the arrangements of these interior structures by presenting the surface features with which they are continuous, and by giving a broad overview of the components of the CNS.

The CNS is composed of the spinal cord and the brain, whose major components are indicated in Figure 1-1. The human brain is dominated by two very large cerebral hemispheres, separated from each other by a deep longitudinal fissure. Each hemisphere is convoluted externally in a fairly consistent pattern into a series of gyri, separated from each other by a series of sulci (an adaptation that makes more area available for the cortex that covers each cerebral hemisphere). Several prominent sulci are used as major landmarks to divide each hemisphere into five lobes\*—frontal, parietal, occipital, temporal and limbic—each of which contains a characteristic set of gyri (indicated in Figures 1-2–1-4). The two hemispheres are interconnected by a massive bundle of nerve fibers, the corpus callosum. Finally, certain areas of gray matter called basal ganglia (or, more properly, basal nuclei) are embedded in the interior of the CNS, primarily in the cerebral hemispheres; they are apparent in the brain sections shown in Chapters 5–7.

\*In addition, the insula, an area of cerebral cortex buried deep in the lateral sulcus (e.g., Figure 5-6, A) is usually considered as a separate lobe.

The cerebral hemispheres of humans are so massive that they almost conceal the remaining major subdivisions of the brain—the diencephalon, brainstem and cerebellum. Hemisecting a brain in the midsagittal plane, as in Figure 1-1B, reveals these components.

The diencephalon (literally the “in-between-brain”) is interposed between each cerebral hemisphere and the brainstem. The diencephalon contains the thalamus, a major waystation for information seeking access to the cerebral cortex; the hypothalamus, a major control center for visceral and drive-related functions; and several other structures.

The brainstem, continuous caudally with the spinal cord, serves as a conduit for pathways travelling between the cerebellum or spinal cord and more rostral levels of the CNS. It also contains the neurons that receive or give rise to most of the cranial nerves.

The cerebellum is even more intricately convoluted than the cerebral hemispheres, to make room for an extensive covering of its own cortex. It plays a major role in the planning and coordination of movement. A deep transverse fissure (normally occupied over most of its extent by the tentorium cerebelli) separates the cerebellum from the overlying occipital and parietal lobes and then continues deeper into the brain, partially separating the diencephalon from the cerebral hemispheres.

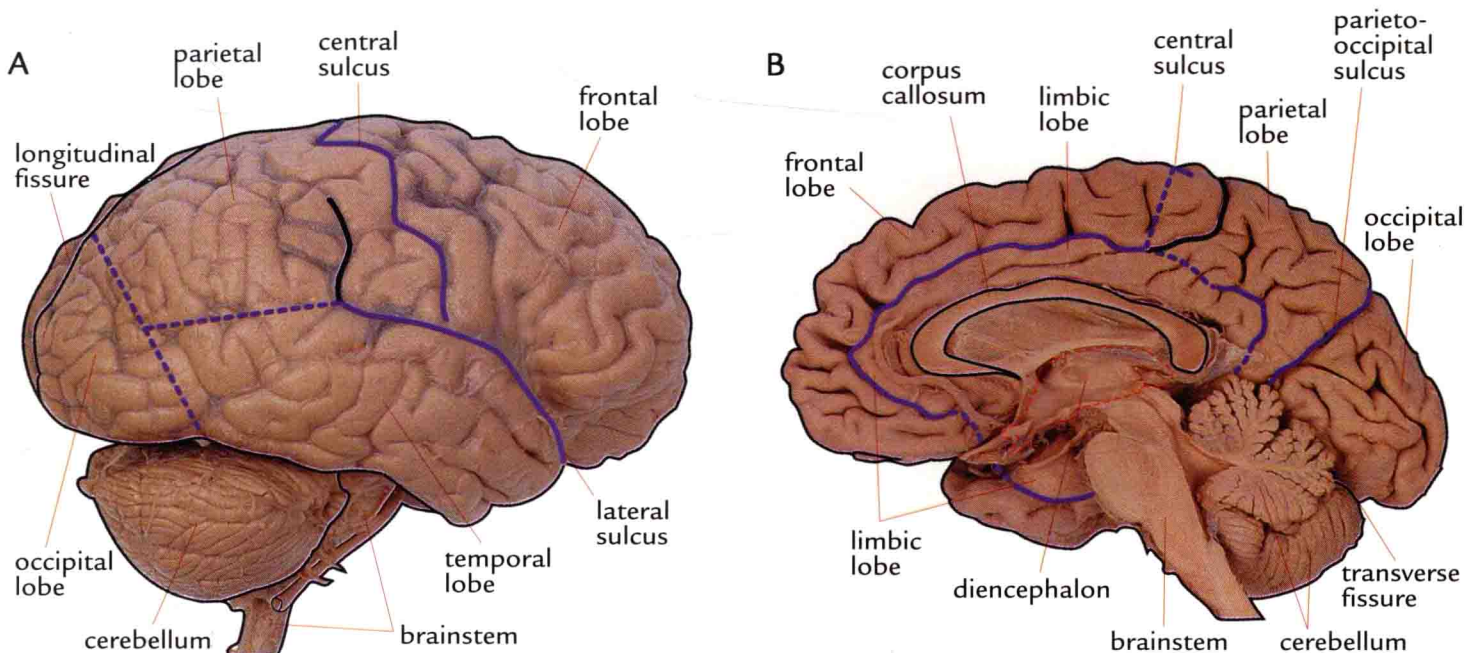




Figure 1-1. Lateral and medial surfaces of the brain, shown slightly less than half actual size. **A**, the right lateral surface of the brain shown in more detail in Figures 1-2 and 1-3; anterior is to the right. The view is from slightly posterior, so a bit of the left hemisphere can be seen on the other side of the longitudinal fissure. The arachnoid was not removed from this specimen, but major gyri and sulci are still readily apparent. **B**, the medial surface of the right half of the sagittally hemisected brain shown in more detail in Figure 1-4; anterior is to the left. In this case the arachnoid was removed. (Dissections courtesy of Grant Dahmer, Department of Anatomy, The University of Arizona College of Medicine.)



The image displays two anatomical diagrams of the human brain, labeled 'a' and 'b', with various structures identified by text labels and leader lines. Some labels are enclosed in blue hand-drawn boxes.

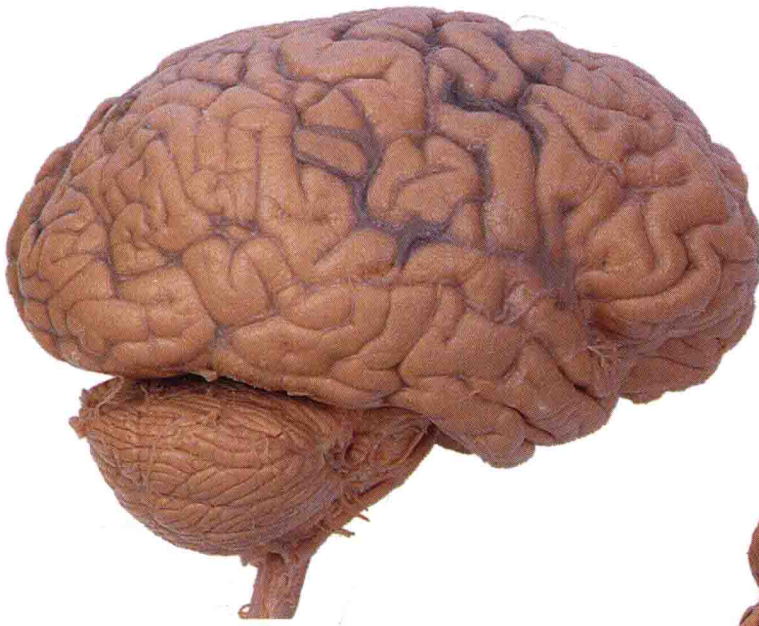
**Diagram 'a' (Lateral View):**

- Frontal lobe:** frontal gyri (superior, middle, inferior); inferior frontal gyrus (1. orbital part, 2. triangular part, 3. opercular part); orbital gyri.
- Central sulcus** (boxed).
- Parietal lobe:** precentral gyrus (boxed); postcentral gyrus (boxed); supramarginal gyrus; superior parietal lobule; intraparietal sulcus; angular gyrus (boxed).
- Occipital lobe:** occipital lobe.
- Temporal lobe:** temporal gyri (superior, middle, inferior); lateral sulcus (boxed).
- Cerebellum:** cerebellum (hemisphere); cerebellum (flocculus).
- Other:** transverse fissure; preoccipital notch.

**Diagram 'b' (Medial View):**

- Frontal lobe:** frontal gyri (superior, middle, inferior).
- Central sulcus** (boxed).
- Parietal lobe:** precentral gyrus; postcentral gyrus; supramarginal gyrus; superior parietal lobule; intraparietal sulcus; angular gyrus.
- Occipital lobe:** occipital lobe.
- Temporal lobe:** temporal gyri (superior, middle).
- Cerebellum:** cerebellum (flocculus).
- Other:** longitudinal fissure (boxed); arachnoid granulations.

Figure 1-2, continued. Lateral and superior surfaces of the cerebral hemispheres.



**C.** Lateral view of the right hemisphere of the same brain shown in **A** and **B**. Although the two cerebral hemispheres of human brains are approximately mirror images of each other, some slight asymmetries are common, particularly in certain language-related areas. Note in this specimen how much farther posteriorly the lateral sulcus extends in the left hemisphere (**A**), and how much larger the triangular part of the inferior frontal gyrus is on the left.

**D.** The same hemisphere as in **C**, seen from a more anterior and superior vantage point.

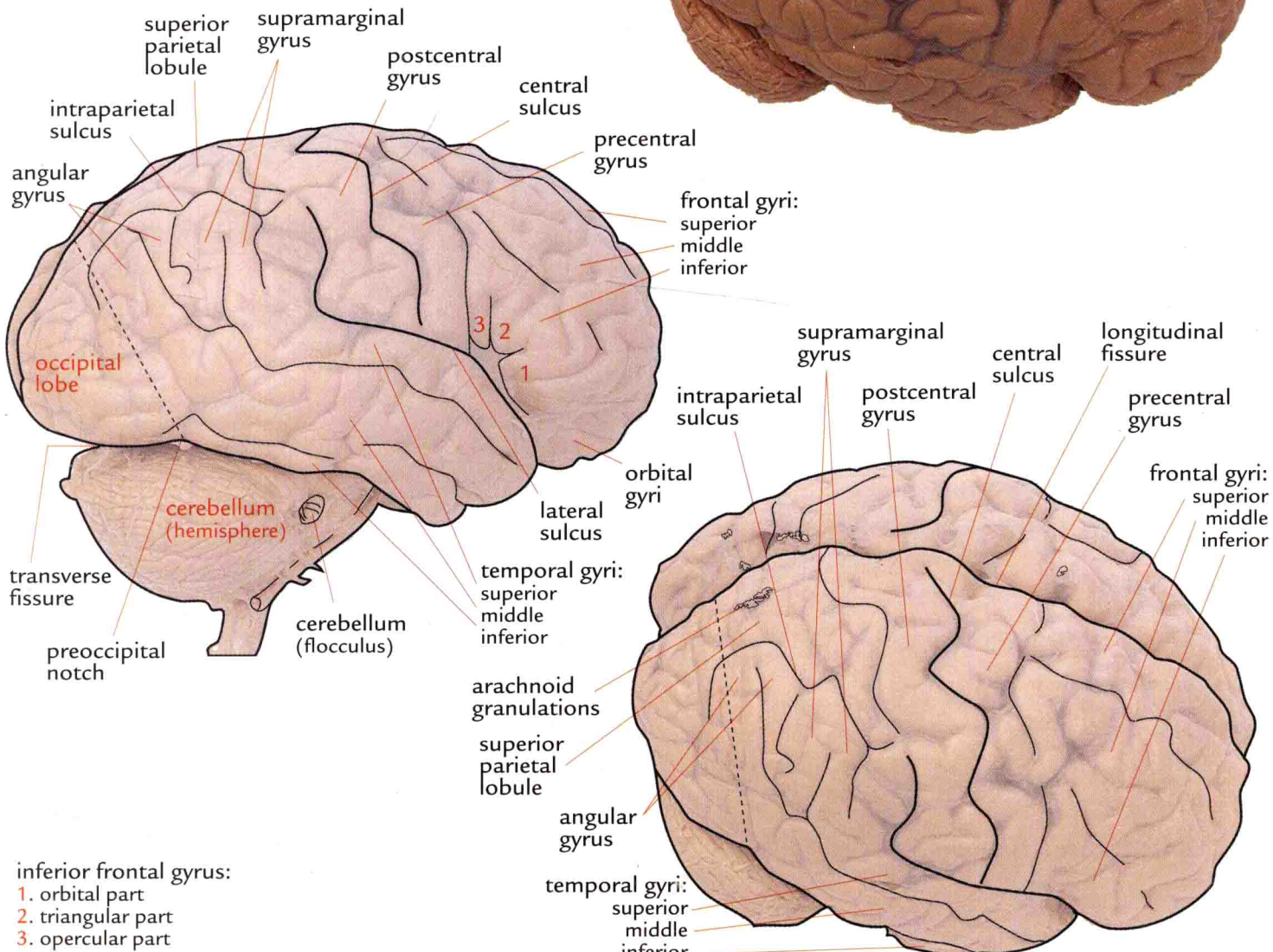
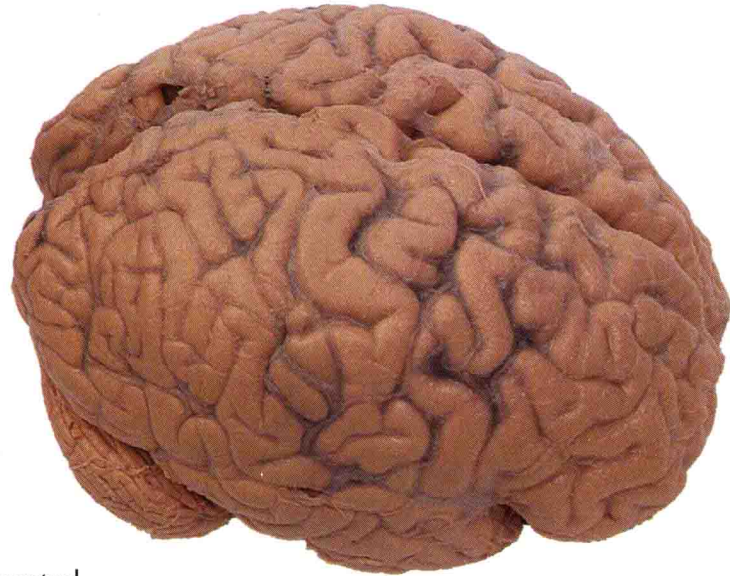


Figure 1-3, A. Inferior surface of the same brain as in Figure 1-2, shown at about two thirds actual size. (Dissection courtesy of Grant Dahmer, Department of Anatomy, The University of Arizona College of Medicine.)

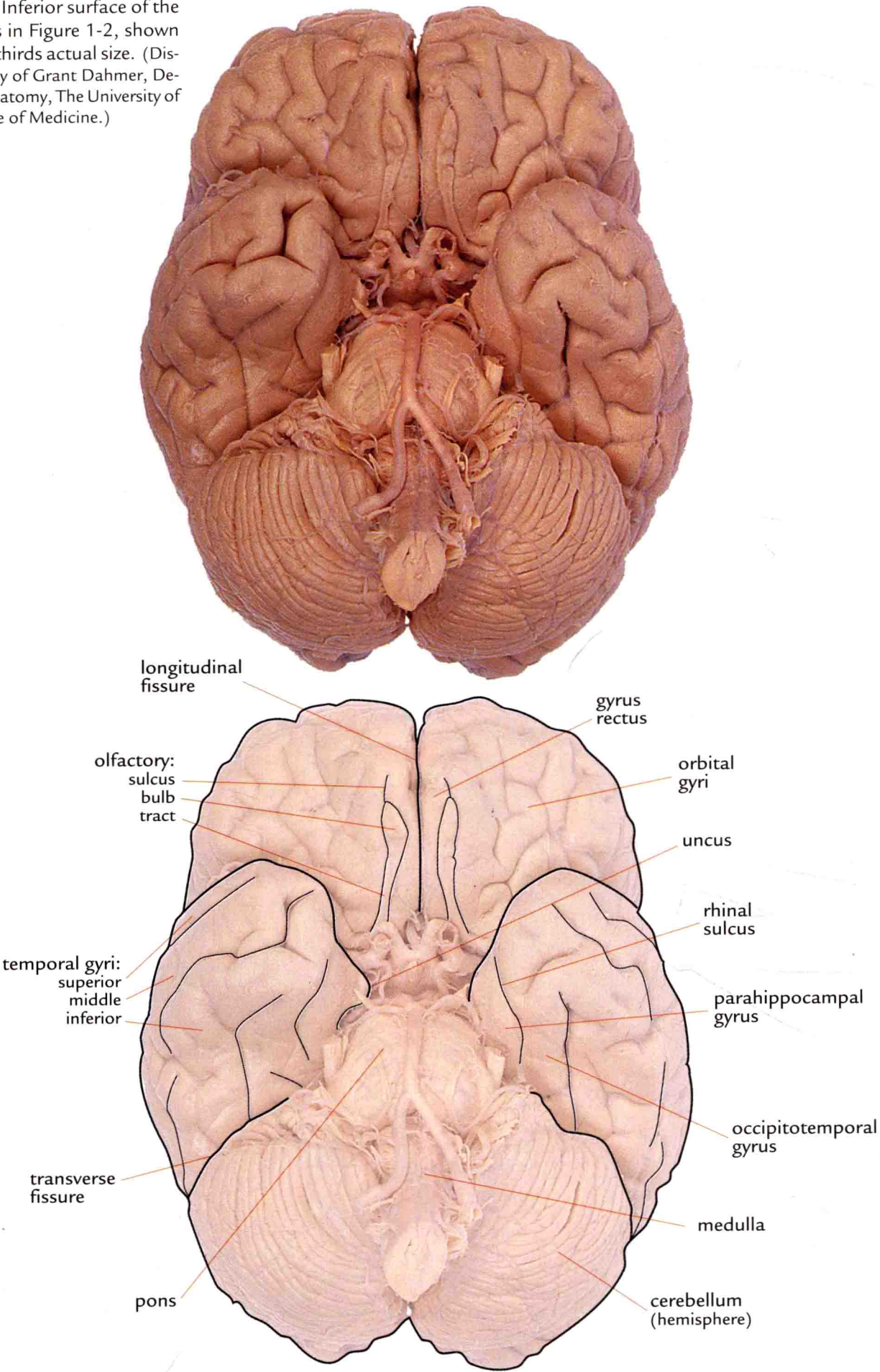


Figure 1-3, B. The brainstem and the base of the forebrain, shown at about 1.2x actual size.

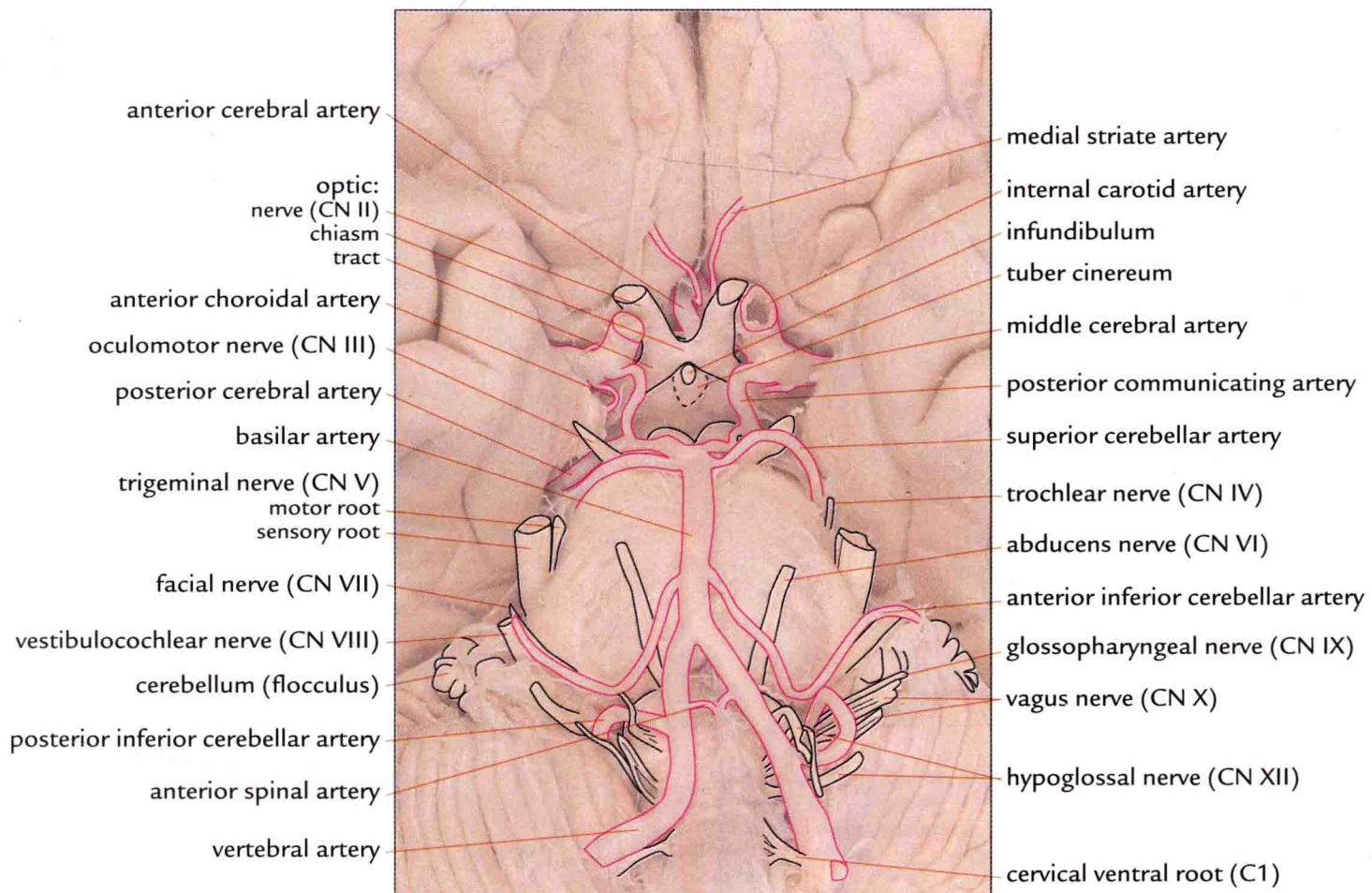
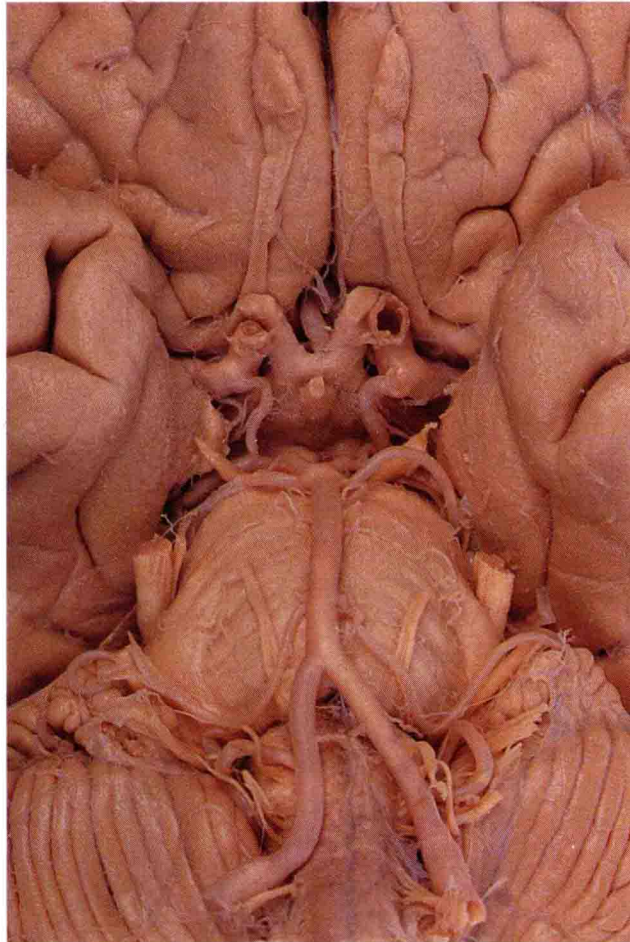


Figure 1-4, A. Medial surface of the right half of a sagittally hemisected brain, shown actual size.  
(Dissection courtesy of Grant Dahmer, Department of Anatomy, The University of Arizona College of Medicine.)

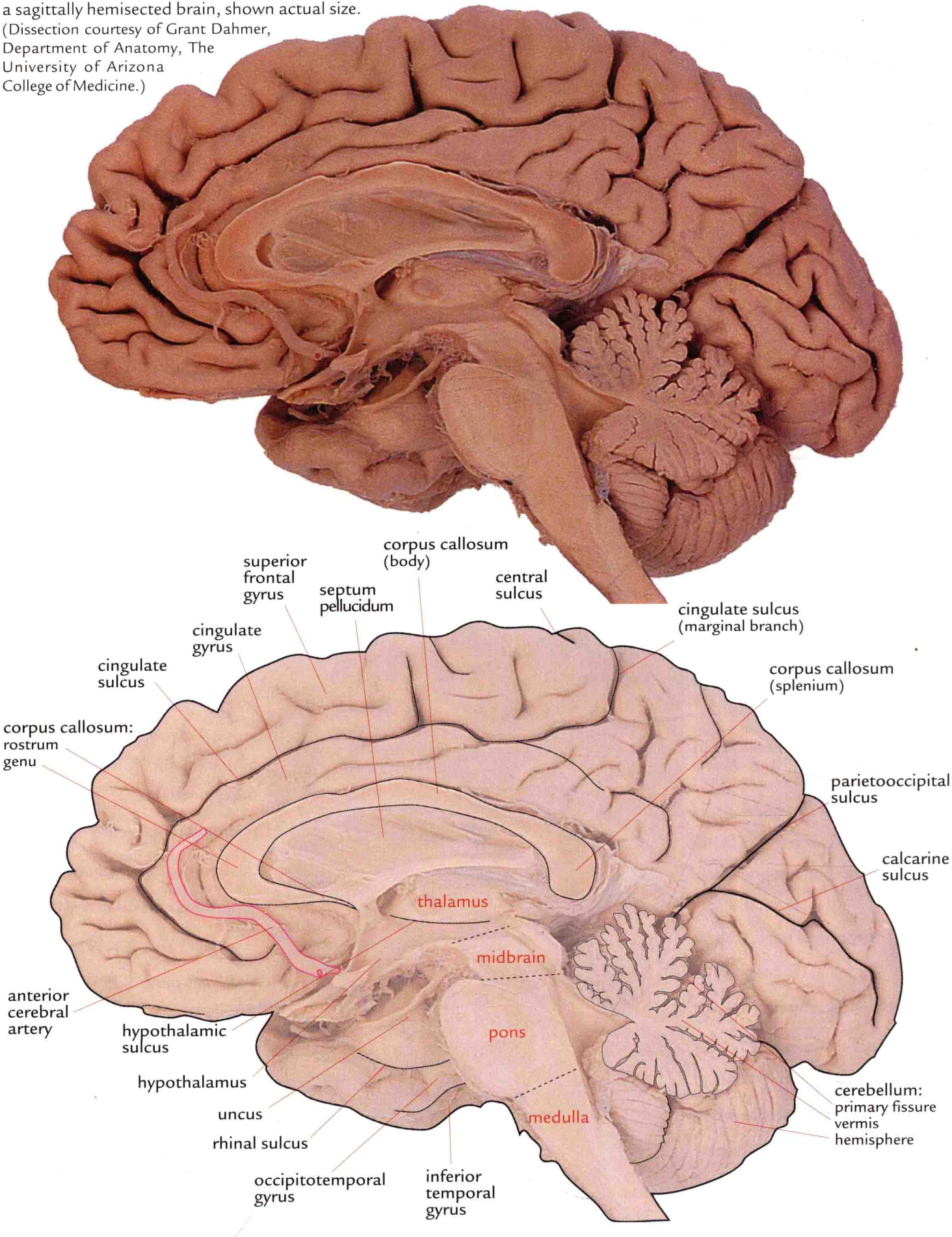


Figure 1-4, B. The diencephalon and part of the brainstem , shown at about 1.7x actual size.

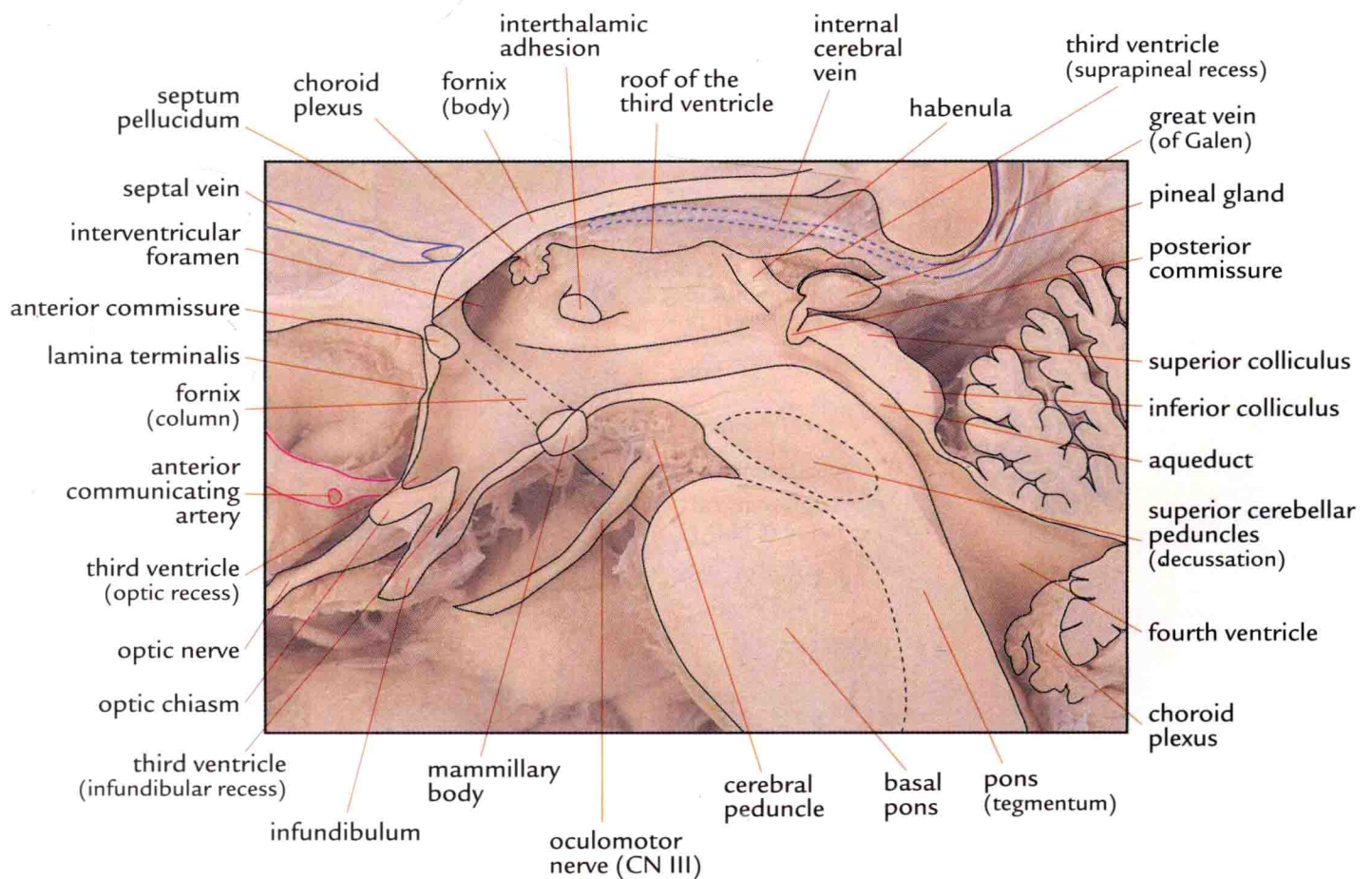
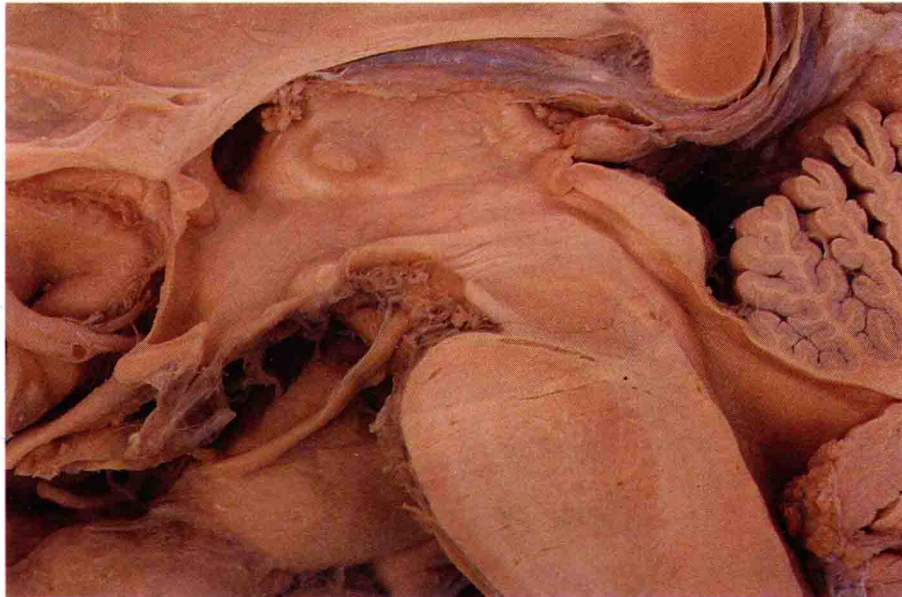
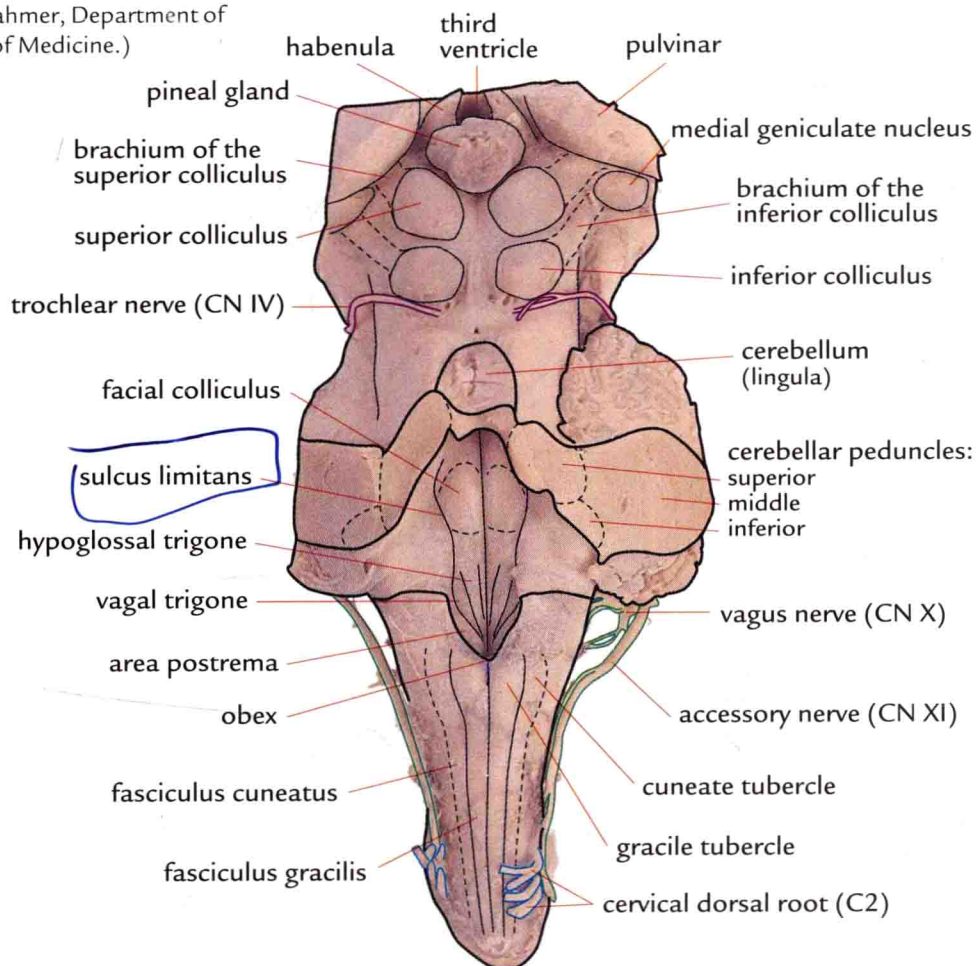
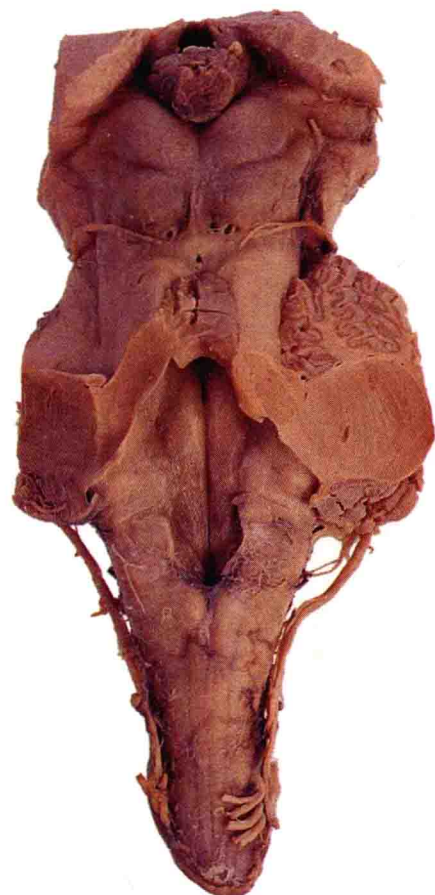


Figure 1-5. Four views of a brainstem, shown at about 1.3x actual size. (Dissection courtesy of Grant Dahmer, Department of Anatomy, The University of Arizona College of Medicine.)



A (above). The dorsal surface, looking down on the floor of the fourth ventricle.

B (below). The ventral surface.

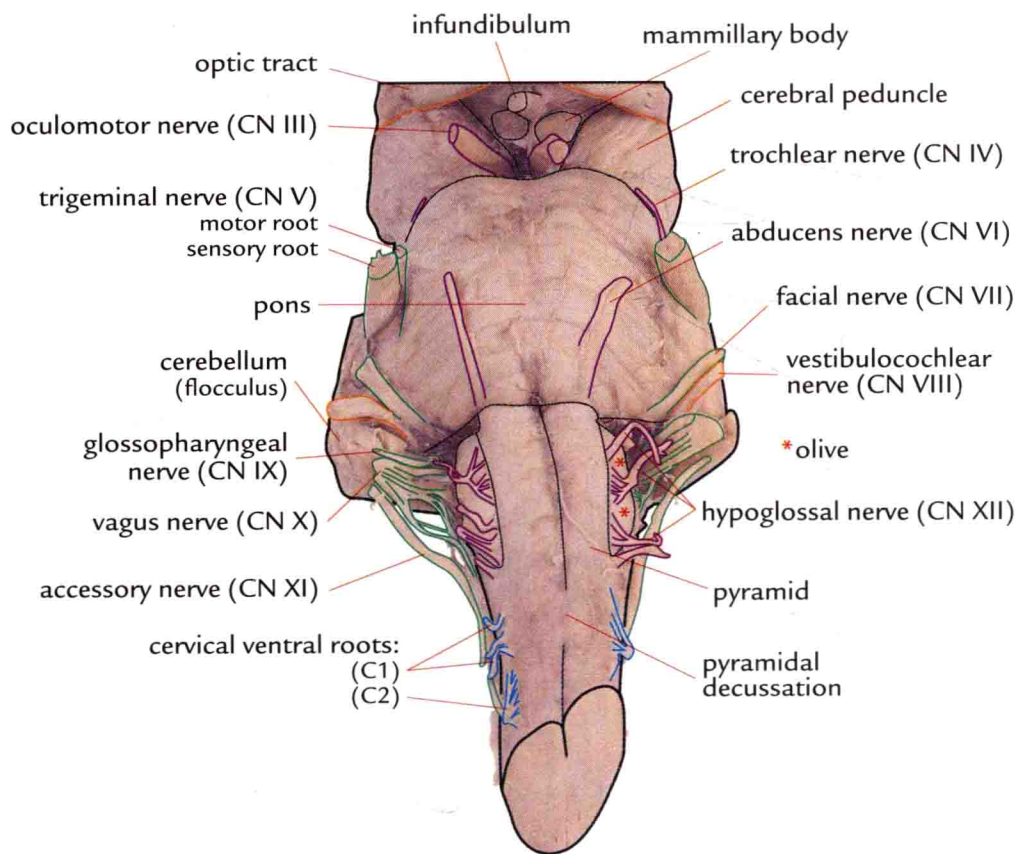
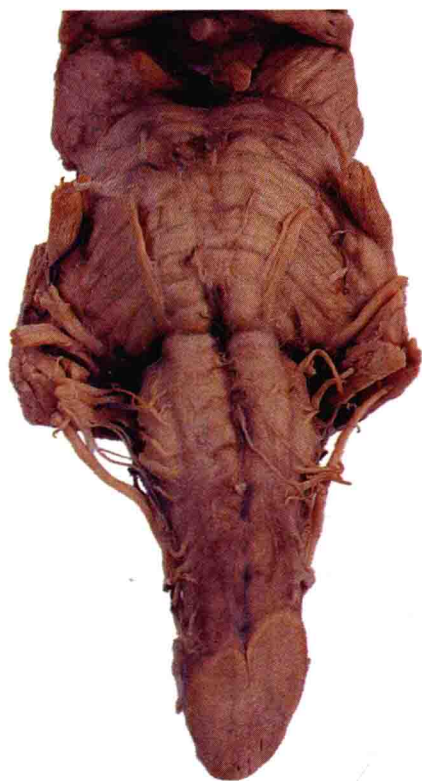
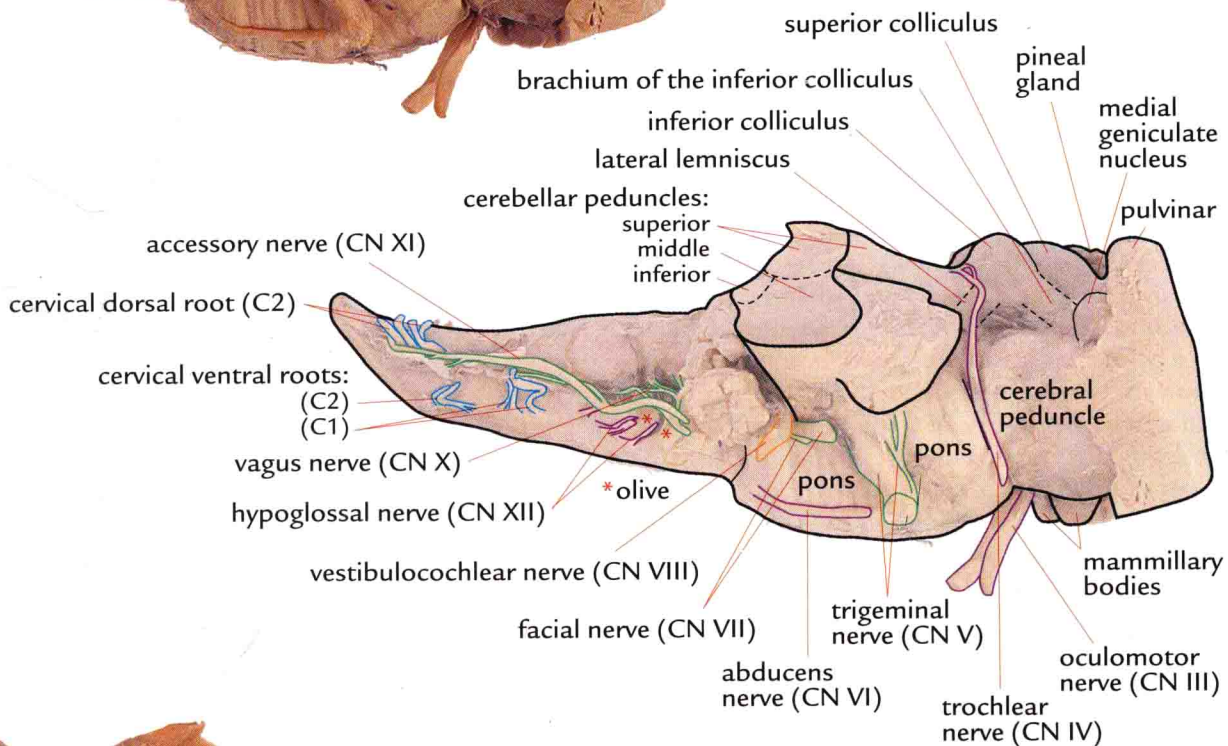


Figure 1-5, continued. Four views of a brainstem.



C. Right side.



D. Left side.

