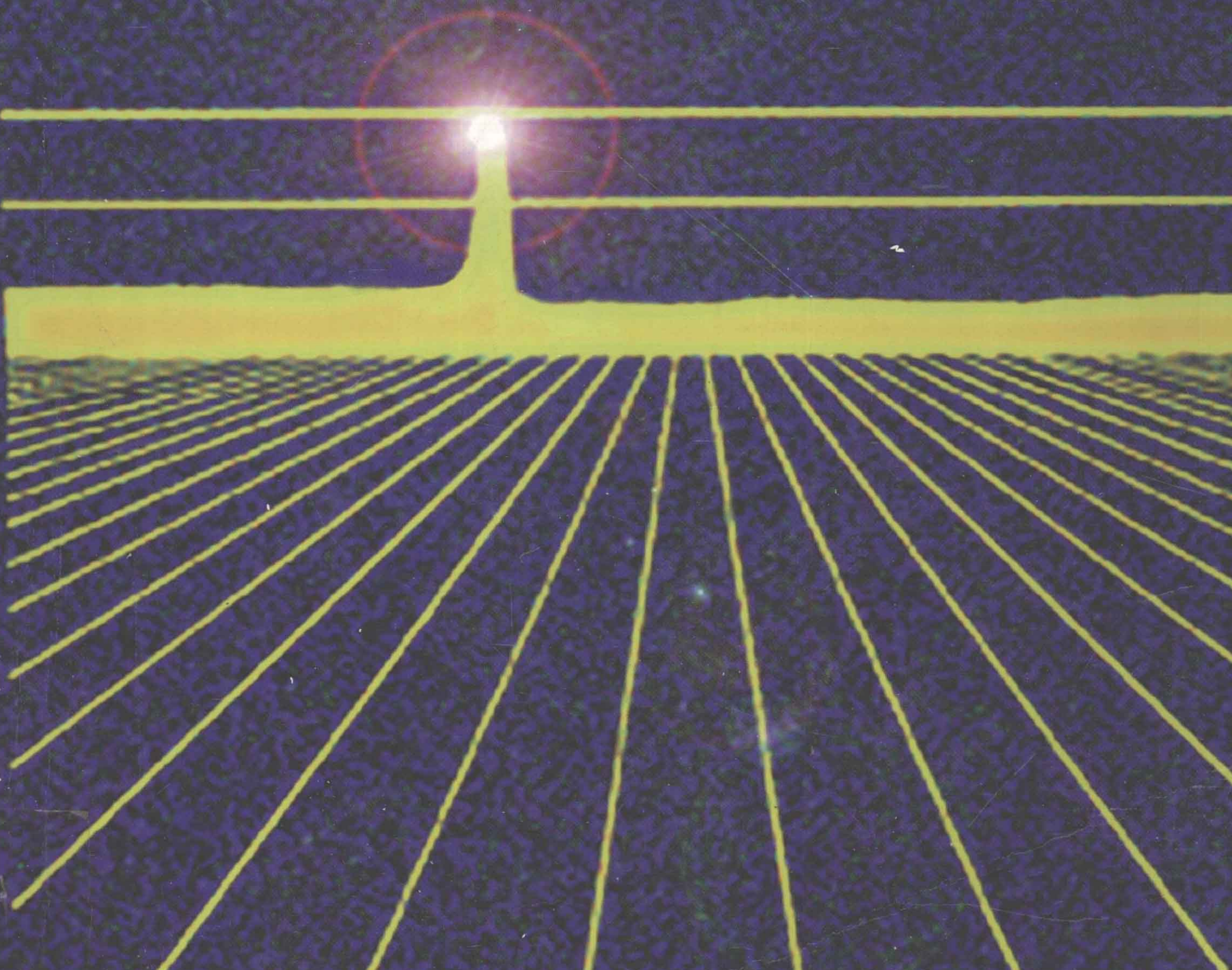
CONCISE TEXT OF NEUROSCIENCE



ROBERT E. KINGSLEY

Concise Text OF Neuroscience

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Dedicated to

W. v B. and R. D.,

whose tragic deaths helped inspire and motivate me, and also to the under-appreciated medical student, in whose hands ultimately rests the future of medicine.

PREFACE

The purpose of this book is to provide medical students with a concise presentation of brain anatomy and function in a form that is relevant to clinical practice. To do this, I feel it is necessary to present the subject matter of neuroanatomy, neurophysiology, and neurology together, in one place, integrated into a cohesive unitary structure—Neuroscience.

The size of the Neuroscience knowledge base precludes presenting a complete, systematic Neuroscience course to first-year medical students in the single semester typically allotted in medical curricula. This has necessarily placed severe limits on the amount and nature of the information that could be included in this book. Therefore, this is not intended to be a comprehensive work, but rather a practical textbook tailored specifically to the needs of the medical student. The greatest challenge in writing a Neuroscience textbook for medical students lies in selecting the subset of information such a book must contain. This particular book has been assembled with a close eye on the ultimate clinical usefulness of the information included. Of course, the selection of material has also been shaped by the special interests and knowledge of the author. Therefore, the final presentation of Neuroscience in this textbook represents my personal view of the core knowledge of Neuroscience appropriate to the practice of medicine.

It was with some concern that I chose to omit an extensive bibliography in this book. By omitting it I certainly do not wish to imply that the information presented here is original. It certainly is not. Nor do I wish to imply that factual statements cannot be documented in the original literature. They certainly can be. However, in keeping with the philosophy that this book is intended for medical students, who typically do not have the opportunity or the time to consult the original literature, extensive documentation and footnotes seemed to be more of a distraction than an aid. I have chosen instead to include a short list of secondary references that students may consult for further detail on the subjects presented. These sources also contain sufficient reference to the primary literature.

The size and rate of expansion of knowledge about the nervous system certainly precludes any one individual from having a complete or current understanding of this complex organ system. Writing a book of this nature makes one deeply aware of one's limitations and the remarkable contributions so many people have made to the field of Neuroscience. There are literally thousands of people whose sweat and toil in their research laboratories have made a book like this possible. Giving appropriate credit to all of them for their discoveries in any textbook is impossible; in a limited book such as this, entirely hopeless. Expressing the humility I feel in the presence of a research community that has so broadened our understanding of the human brain is the only acknowledgment I can extend. I do so with gratitude.

This book would not have been possible without the direct help and encouragement of many people. Foremost among these is T. R. Kingsley. Her unvarnished criticism, precise and detailed, and her very specific and useful suggestions have contributed immeasurably to the quality of this text. In addition, if she had not also volunteered to write the embryology appendix, that important topic would certainly be missing from these pages. Steve Gable read every word of this text and offered many important and useful contributions. In particular, he helped keep the focus of the text where it ultimately must be, on the patient suffering from neurological disease. Michael Hancock, Deloris Schroeder, and Jude Berman read the entire manuscript, made many important suggestions, and ferreted out errors. Arnold Hassen read several chapters and offered useful criticism and welcome encouragement. Mike Lannoo used a preliminary version of this work in the classroom; his comments and those of the freshman medical students at Muncie and South Bend were extremely valuable in shaping the final manuscript.

The inclusion of the clinical material found in this book would not have been possible without the help and cooperation of the Saint Joseph's Medical Center and the Magnetic Resonance Imaging Center, especially John Harding, Vic Jones, Tobin Mathews, and Barb Brown, who collected the material for me. Mary Donigan was very helpful in obtaining appropriate audiological material, while Bob King, Carl Marfurt, Mark Walsh, and Susan White kindly provided me with several cases. Former medical students C. L. Watts, J. L. Lackman, Janice Peterson, and Dennis Mishler collected most of the other cases.

The usefulness and beauty of this book have been materially enhanced by the superb illustrations of Jacqueline Schaffer and Mollie Dunker. Several people offered for my use original prints of micrographs. I especially thank Richard Coggeshall, Steve Flieslor, Larry Squire, Gary Wright, and Jaime Dant, who generously provided outstanding examples of their work. The cover illustration was created by Caryl Erickson. The endsheets were kindly provided by the Eastman Kodak Co.

I would also like to acknowledge the assistance of Kathleen Drajus, who spent many hours obtaining and collecting copyright permissions and obtaining references for me from numerous libraries, and Marilyn Wacker of the Ruth Lily Library. Connie Gordon and Diane Huddlestun supported me in numerous ways, for which I am very grateful.

This book would not have been possible without David Burr, who first encouraged me to proceed with the project; Tim Satterfield, who was willing to take a chance on a new author; and Walter Daly, who arranged leave time that enabled me to complete the manuscript. Finally, and certainly not least, I want to extend my thanks and appreciation to the editorial staff of Williams & Wilkins, especially to Pat Coryell and Nancy Evans, who kept me and this project on track and on time. In spite of all of this help, errors of commission and omission must certainly have crept into the text, and for these I take total responsibility.

R. E. Kingsley
South Bend, 1995

CONTENTS

1 Gross Structure of the Nervous System

The mammalian nervous system is a control system that regulates all functions of the organism. In addition, at least in the human, it has unique functions that are independent of the other organ systems of the body. These independent functions allow us awareness of ourselves. The nervous system performs these functions as an information processing system. Information consists of internal representations of the external world in which the organism exists. The manner in which these internal representations of the world are created, transformed, and used to affect the behavior of the organism is the subject matter of **neuroscience.**

This book presents an introduction to a small segment of **neuroscience**—the part that is of particular concern to the physician. The principal topics that are addressed are the anatomy, physiology, and neurology (nervous system disease) of the human nervous system. The general plan is to present a description of the relevant anatomy of a functional system, followed by a discussion of its physiology. Then the neurology associated with that system is presented and, in most chapters, illustrated with case histories.

This chapter describes the surface features of the nervous system. The deep structures of the nuclei and tracts are dealt with separately in succeeding chapters. This description is not meant to be complete. It is a general overview for purposes of orientation and familiarization. It is essential that every physician know the structures described in this chapter, because they form the basis for one's visualization of the brain and one's ability to communicate about the brain with others. The purpose of this chapter is to lay a foundation that will enable one to develop a workable association between names and visualized structures, an association that is indispensable to understanding.

The central nervous system consists of the **brain,** the **brainstem,** the **cerebellum,** and the **spinal cord** (Fig. 1.1). The brain can be further divided into the **cerebral hemispheres** and **basal ganglia** (telencephalon), and the **thalamus** (diencephalon). The brainstem consists of the **midbrain** (mesencephalon), the **pons** (metencephalon without the cerebellum), and the **medulla** (myelencephalon).

The Cerebral Hemispheres and Basal Ganglia

The cerebral hemispheres form the largest part of the telencephalon, a paired structure that is the most prominent feature of the mammalian nervous system. The basal ganglia are a collection of closely associated nuclei that lie deep in the telencephalon and present no surface features. They are discussed in Chapter 8.

THE CEREBRAL HEMISPHERES

The visible, superficial portions of the telencephalon are the two cerebral hemispheres, separated by the **longitudinal cerebral fissure** and joined by a massive collection of axons, the **corpus callosum** [L. *corpus,* body, + L. *callosus,* hard] (Figs. 1.2 and 1.3). The cerebral hemispheres are the result of an extreme elaboration of the superficial embryonic telencephalon. This

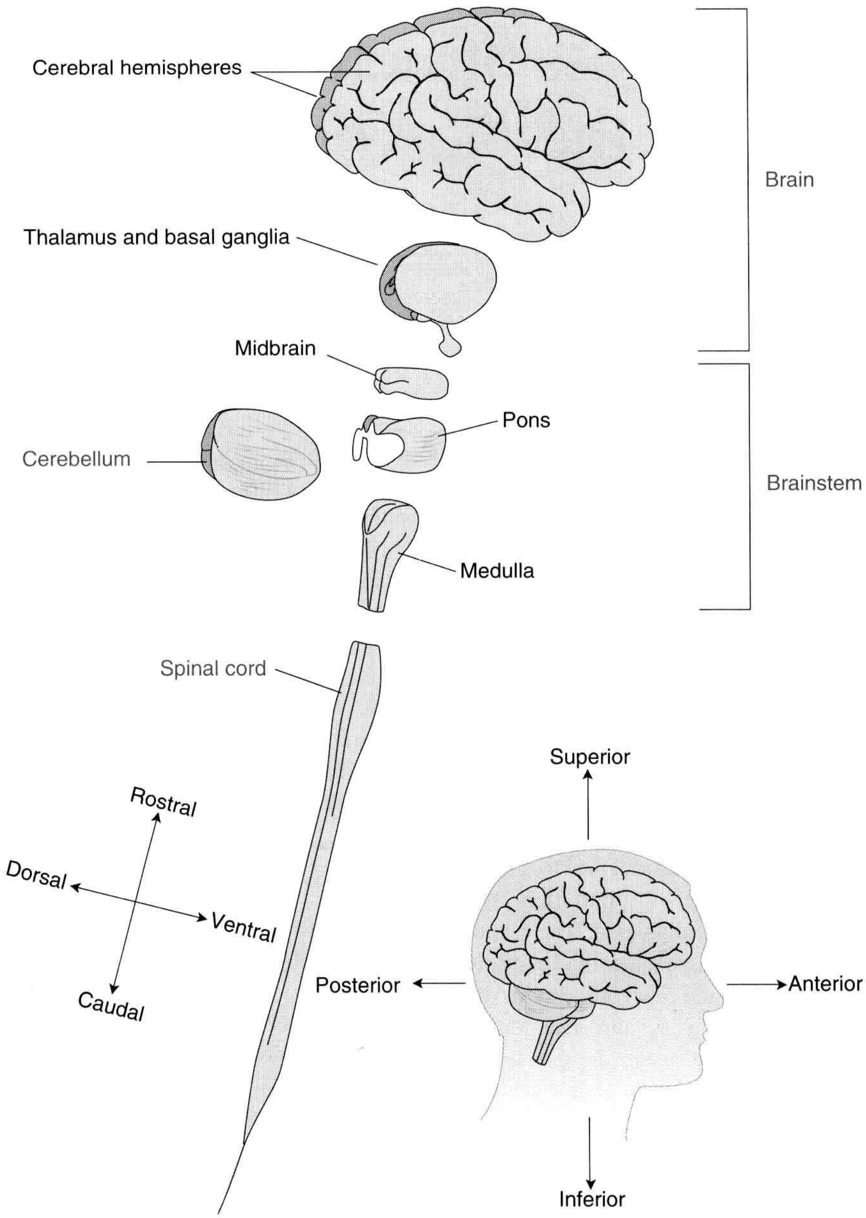

FIGURE 1.1.

Schematic drawing illustrating the relationships among the major divisions of the central nervous system. Note that the terms *superior, inferior, anterior,* and *posterior* are traditionally used to describe direction for the telencephalon, diencephalon, and cerebellum. The terms *dorsal, ventral, rostral,* and *caudal* are used for the remaining divisions. *Rostral* and *caudal* are frequently used for all parts of the central nervous system, rostral meaning "toward the head" and caudal, "toward the tail." Many authors use *posterior* and *anterior* interchangeably with *dorsal* and *ventral*. The choice is mostly a matter of style.

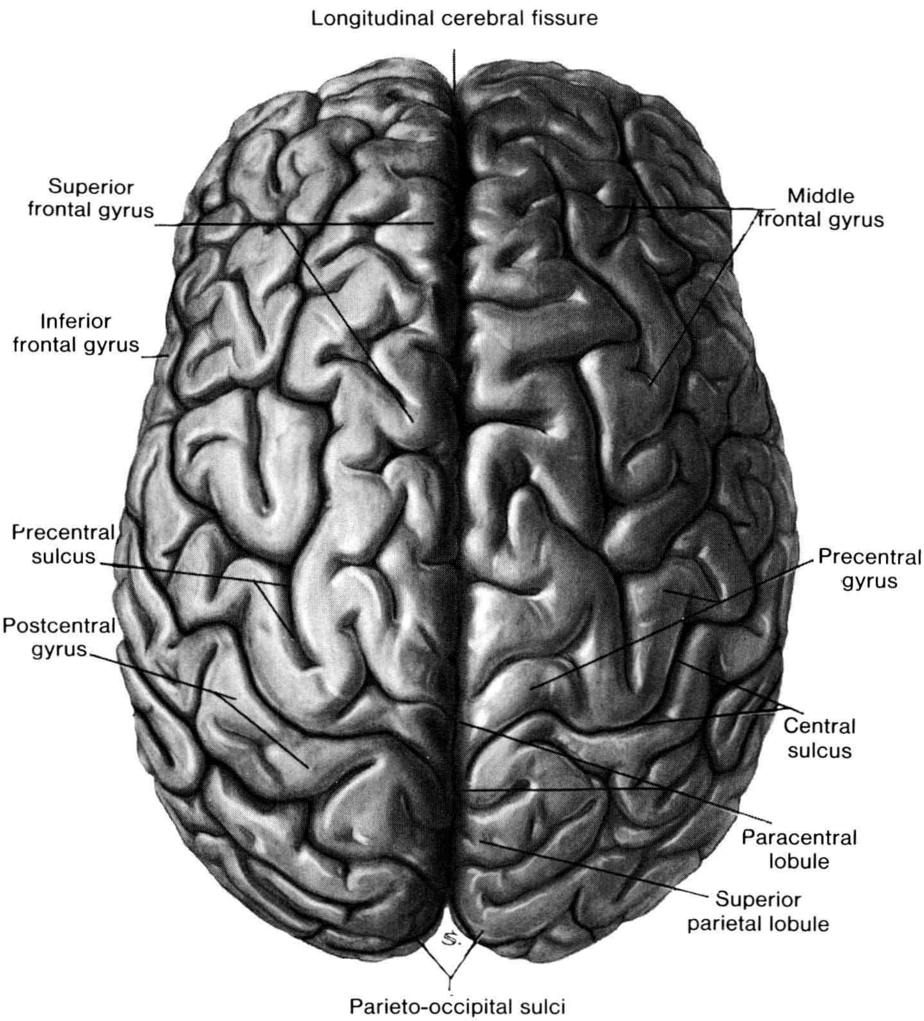

FIGURE 1.2.

The superior surface of the cerebral hemispheres. They are separated by the longitudinal cerebral fissure. Note particularly the location of the central sulcus and the precentral and postcentral gyri. Note also the three frontal gyri.

elaboration is so extensive that the surface, the **cerebral cortex** [L. *cortex,* bark], becomes wrinkled during development. This wrinkling allows the cortical surface area to be greatly expanded while the volume enclosed remains at a minimum. A convex extension of the cortical surface is a **gyrus** [L. *gyros,* circle] and a concave fold, a **sulcus** [L. *sulcus,* furrow or ditch]. A particularly deep sulcus is frequently called a **fissure.**

The pattern of gyri on the surface of the hemispheres is not random. Within any mammalian species, the pattern of gyri and sulci remains remarkably similar among individuals. This pattern establishes useful landmarks and should be memorized. Using these patterns, one can divide each hemisphere into five lobes (Figs. 1.3 and 1.4). The greatest of the wrinkles results, during fetal development, in part of the cerebral cortex, the **insular lobe,** being buried beneath cortical tissue that expands over it from two directions. The part of the cerebral cortex that covers the insular lobe is known as the **operculum** [L. *operculum,* a cover or lid]. Where these two sheets of cortex meet, a furrow is formed, the **lateral fis-**

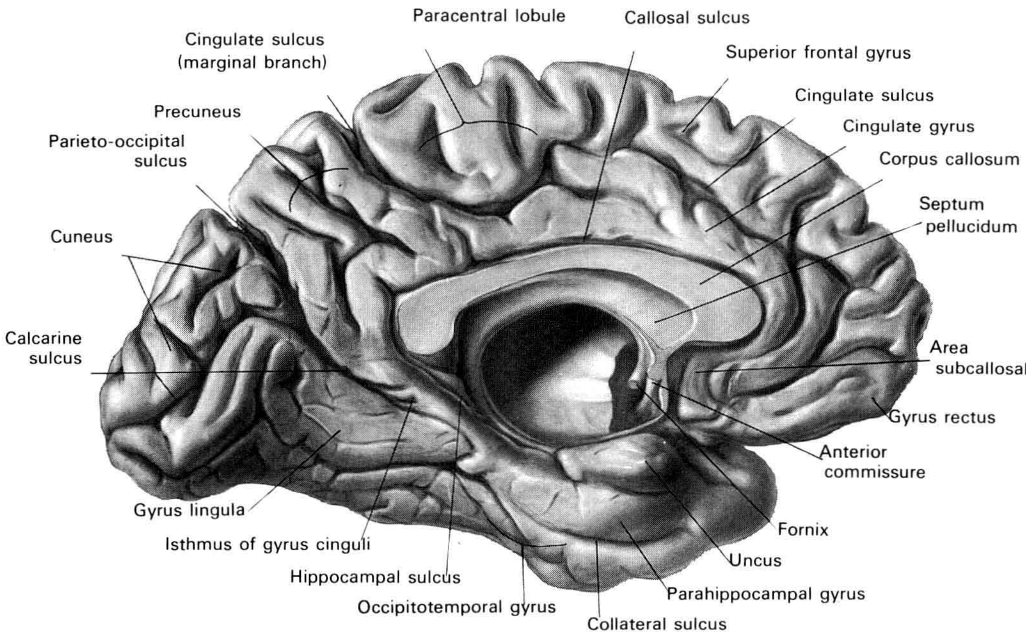

FIGURE 1.3.

Medial view of the left cerebral hemisphere. The corpus callosum has been cut in the midsagittal plane. If one follows the cingulate sulcus to the superior surface of the hemisphere, the postcentral gyrus lies immediately anterior to it. Moving anterior to the next sulcus, one finds the central sulcus. This is the most reliable method of identifying the central sulcus and is especially useful when interpreting magnetic resonance images. The parieto-occipital sulcus is easily identified on the medial surface of the hemisphere, and it meets the calcarine sulcus at nearly a right angle in most brains.

sure. This fissure separates the **temporal lobe** from the remaining cortical mass. Joining the lateral fissure at nearly right angles, the **central sulcus** separates the **frontal lobe** from the **parietal lobe.** The parietal lobe is separated from the **occipital lobe** by the **occipital-parietal fissure,** located on the medial wall of the hemisphere.

The Frontal Lobe

The largest of the five lobes, the frontal lobe is greatly expanded in the human compared to the other primates. On its superior-lateral surface (Figs. 1.2 and 1.5), the **precentral** gyrus spans across the hemisphere from the lateral fissure to the longitudinal cerebral fissure that separates the two hemispheres in the sagittal plane. Anterior to the precentral gyrus are three parallel gyri that are perpendicular to it, the **superior, middle,** and **inferior** frontal gyri. On the inferior surface (Fig. 1.6), at the most medial edge of the hemisphere, lies the **gyrus rectus,** so named because it is unusually straight. The **olfactory tract** with its terminal **olfactory bulb** lies adjacent to the gyrus rectus in a depression known as the **olfactory groove.** Directly over the orbit lie several small gyri known collectively as the **orbital gyri.**

The Parietal Lobe

The anterior margin of the parietal lobe is denoted by the central sulcus, while the anterior portion of its inferior border is defined by the lateral fissure. Its most posterior regions are ill-defined on the lateral surface. One must view the hemisphere from the medial side (Fig. 1.3) to locate the definitive landmark that separates the parietal lobe from the occipital lobe, the **parieto-occipital sulcus.** This sulcus extends somewhat onto the superior surface of the hemisphere. To delineate the posterior boundary of

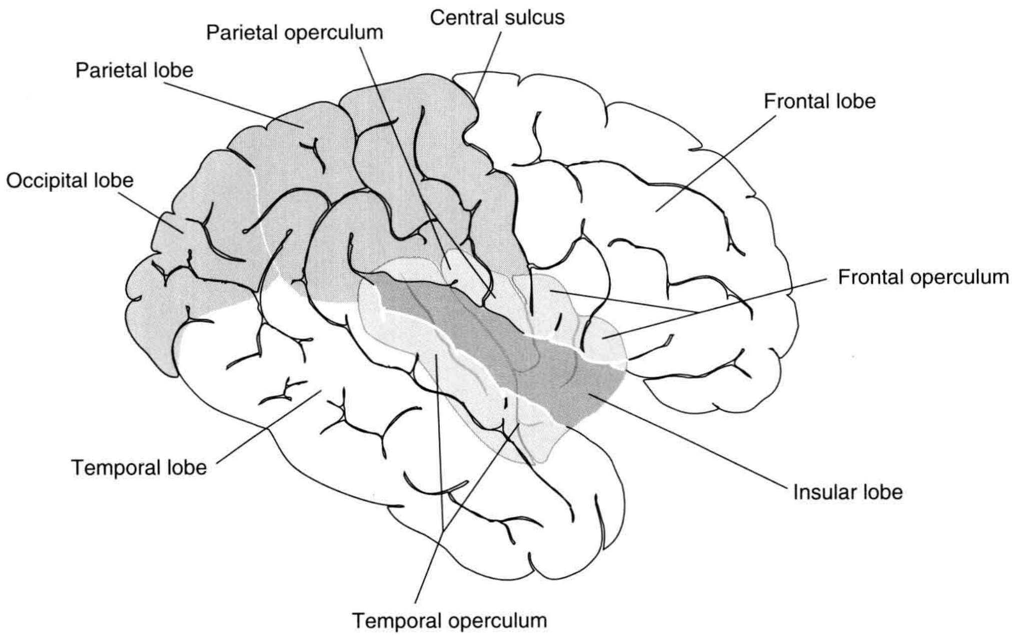

FIGURE 1.4.

Lateral view of the right cerebral hemisphere. The temporal lobe has been pulled away to reveal the insular lobe deep within the lateral fissure. The cortex that lies over the insular lobe is known as the operculum. Note the landmarks that indicate the remaining lobes. The boundaries of the occipital lobe are not obvious on the lateral view. The demarcation between the temporal lobe and the parietal lobe is not designated by any specific landmark.

the parietal lobe on the lateral surface, one must project imaginary extensions of the lateral fissure and the parieto-occipital sulcus. Anterior and superior to these lines lies the parietal lobe (Fig. 1.4).

On the superior-lateral surface of the parietal lobe (Fig. 1.5), the **postcentral gyrus** lies parallel to the central sulcus. Immediately posterior to this gyrus is the **supramarginal gyrus.** It is located immediately superior to the most posterior extent of the lateral sulcus. The **angular gyrus** lies posterior to the supramarginal gyrus.

The most prominent feature of the medial surface of the parietal and frontal lobes is the corpus callosum, a structure that is not a gyrus, but rather a massive collection of axons interconnecting the two hemispheres. This structure extends the entire length of the parietal lobe and well into the frontal lobe (Fig. 1.3). From posterior to anterior, it is divided into the **splenium** [G. *splenion,* a bandage], the **body,** and the **genu** [L. *genu,* knee]. Along its superior margin lies the **callosal sulcus,** and superior to it is the **cingulate gyrus.** The cingulate gyrus is defined on its superior margin by the **cingulate sulcus** [L. *cingulum,* girdle, from *cingo,* to surround].

The Occipital Lobe

Lying posterior to the parieto-occipital sulcus is the occipital lobe, which is relatively small on its lateral aspect (Fig. 1.4). It is divided nearly in two on its medial surface by the **calcarine sulcus** [L., from *calcar,* spur-shaped] (Fig. 1.3). This sulcus joins the parieto-occipital sulcus and then extends along the medial wall of the temporal lobe. In fresh material, if one slices a cross-section perpendicular to the calcarine sulcus, one can see a white stripe in the cortex, following the sulcus and the gyrus on either side. This is the **line of Gennari,** a unique feature of this part of the cerebral cortex, conferring upon it its special name, the **striate cortex.**

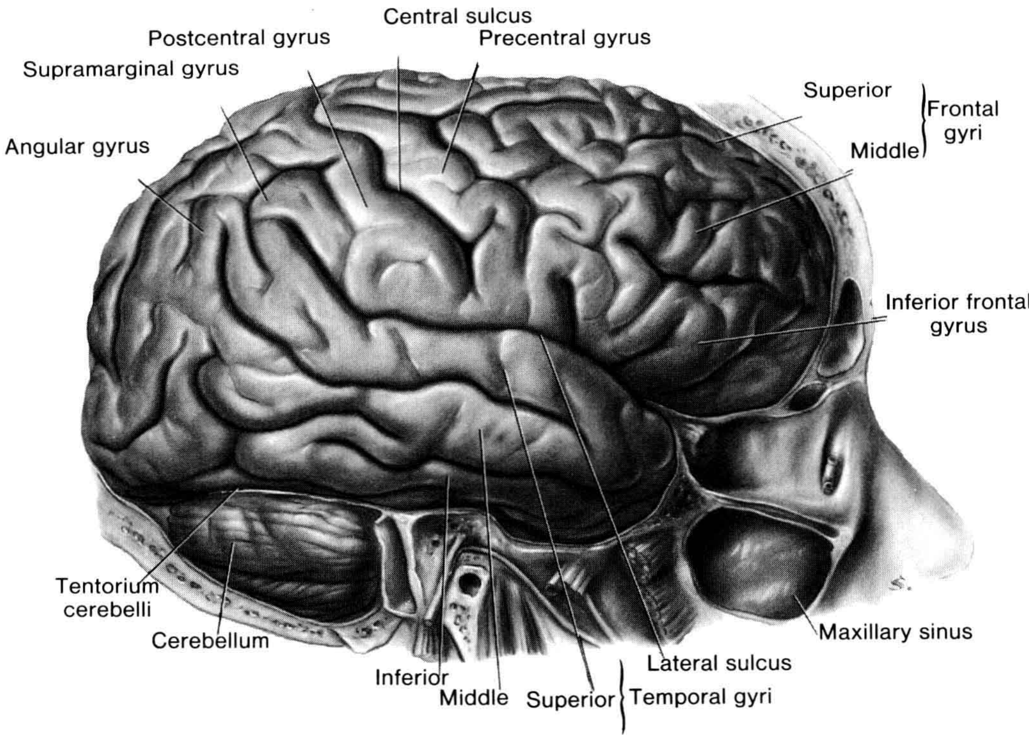

FIGURE 1.5.

The lateral surface of the right cerebral hemisphere. Note how the superior temporal sulcus terminates in the parietal lobe with the angular gyrus wrapped around it. The supramarginal gyrus lies immediately anterior to the angular gyrus.

The Temporal Lobe

Inferior to the lateral sulcus and its imaginary extension and anterior to the parieto-occipital sulcus and its imaginary extension is the temporal lobe (Fig. 1.4). Running approximately in the anterior-posterior direction and parallel with the lateral fissure are three gyri, the **superior, middle,** and **inferior temporal gyri** (Fig. 1.5). The **superior temporal sulcus** separates the superior temporal gyrus from the middle temporal gyrus and extends into the parietal lobe, terminating at the angular gyrus.

The medial surface of the temporal lobe contains several important structures. Most prominent is the **uncus** [L. *uncus,* a hook] (Figs. 1.3 and 1.6), a medial protrusion of the temporal lobe. Deep to it lie the **amygdaloid nuclei** [G. *amygdale,* almond]. Inferior to the uncus is the **parahippocampal sulcus** [G. *hippocampos,* seahorse] and adjacent to it, the **hippocampal gyrus.** Deep to the hippocampal gyrus lies the **hippocampal formation,** an important structure of the temporal lobe that cannot be seen without cutting into it. The parahippocampal gyrus extends along the superior-medial aspect of the temporal lobe, wraps around the splenium of the corpus callosum, and becomes continuous with the cingulate gyrus (Fig. 1.3). At the posterior region, the calcarine sulcus lies inferior to the parahippocampal gyrus.

The Insular Lobe

If one were to widen the lateral fissure, the insula would be brought into view. This small cortical area is completely covered by the operculum of the overlying frontal, parietal, and temporal lobes (Fig. 1.4). Little is known about

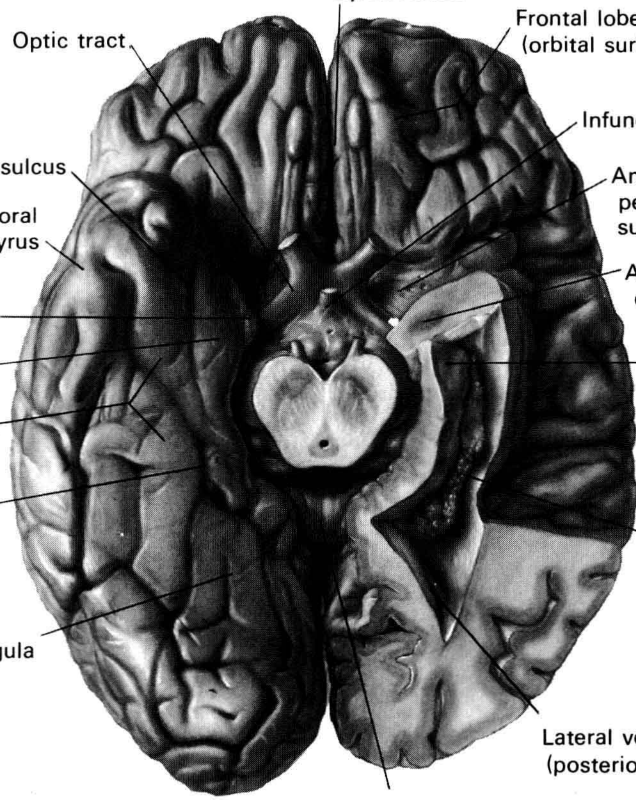

FIGURE 1.6.

A view of the inferior surface of the brain and brainstem.

the functions of the insula and little is to be gained from learning the names of its gyri.

Cortical Maps

At about the turn of the century, a number of neuroanatomists proposed systems by which the cerebral cortex could be subdivided into anatomically distinguishable areas. Most of these systems were based on histological distinctions. Brodmann's map (Fig. 1.7) delineates more than 50 regions. Although the cortical areas were originally differentiated by their histological features, many of the areas have subsequently been found to correlate well with neurophysiological and neurological function. Therefore, Brodmann's map has retained a certain popularity, and many areas of the cerebral cortex are simply referred to by their Brodmann number. In subsequent chapters the Brodmann number of cortical areas will be mentioned when the numbered area is associated with specific neurological functions. For most of the Brodmann areas, however, there is no clear correlation and thus there is no need to memorize the entire map.

THE INTERNAL CAPSULE

The basal ganglia and thalamus, when separated from the cerebral cortex, appear as a large bulbous structure. Dividing it approximately in two is a massive fiber tract, the **internal capsule,** the principal tract connecting the brain with more caudal structures. The internal capsule is broad and fan-shaped as it leaves the

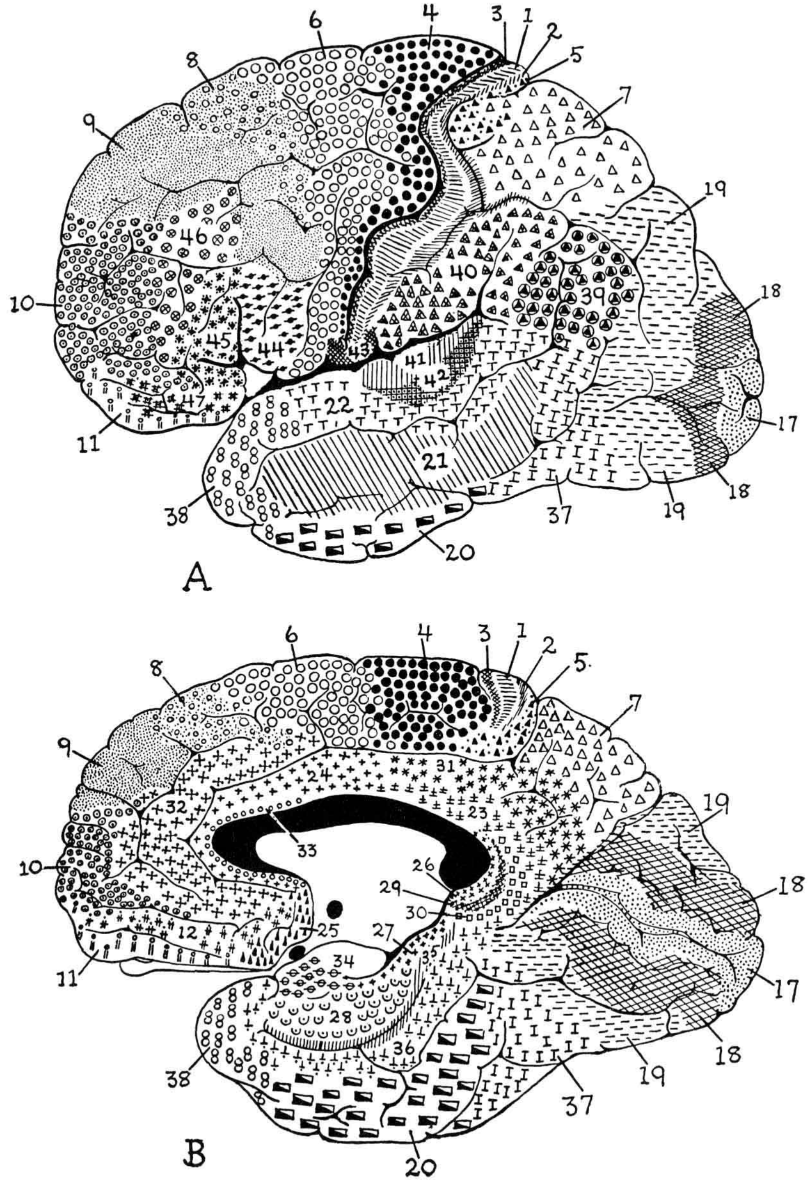

FIGURE 1.7.

Brodmann's cytoarchitectural map of the human cerebral cortex identifies more than 50 areas based on their histological differences. Since some of these areas have distinct neurological functions associated with them, many people refer to them simply by their Brodmann number. These regions are pointed out in the text.

cerebral cortex (Fig. 1.8). Here it is known as the **corona radiata** or "radiating crown." Descending between the thalamus and basal ganglia, the internal capsule loses many fibers to these structures, becomes smaller and more compact, and finally emerges at the rostral end of the mesencephalon as a compact, round structure known as the **cerebral peduncle** [L., from *pes,* foot].

THE BASAL GANGLIA

Medial to the internal capsule lies the head and body of the **caudate nucleus** [L. *cauda,* tail]

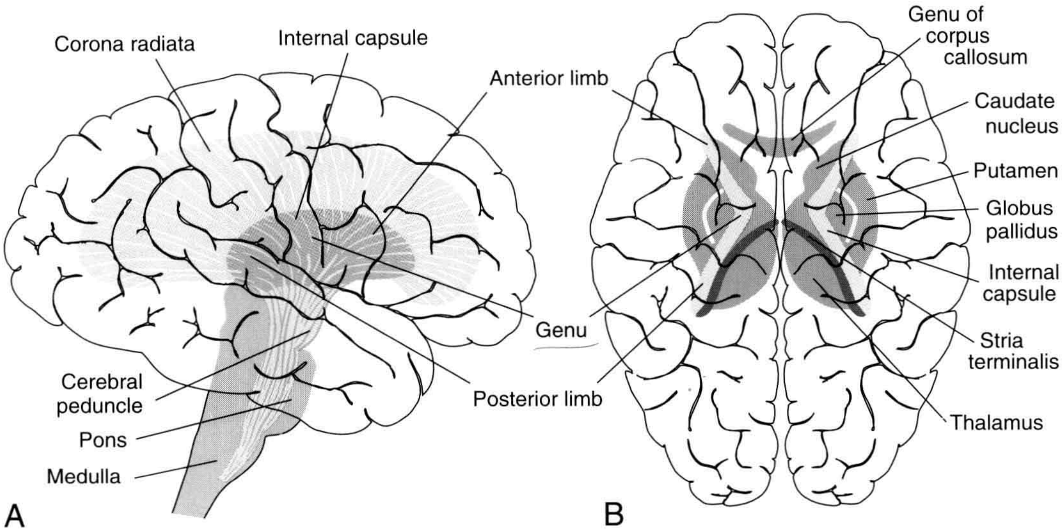

FIGURE 1.8.

A, The corona radiata is the narrow band of axons leaving the cerebral hemisphere. Within the cortical matter, as in this illustration, the structure takes on the appearance of a crown, hence its name. Deeper within the cortex, these same axons form a more compact bundle and are named the internal capsule at the level of the basal ganglion and thalamus. The fibers that continue caudally beyond the thalamus become the cerebral peduncles just before they enter the pons. **B,** Viewed from above, with the superior half of the cerebral hemispheres removed, the internal capsule is shaped like a V. Three divisions are usually identified: the anterior and posterior limbs with the intervening genu. Note how the putamen and globus pallidus are separated from the caudate nucleus by the anterior limb and from the thalamus by the posterior limb.

and the body of the **thalamus** [G. *thalamos,* a bedroom]. Lateral to it is the **putamen** [L. *puto,* to prune] and the **globus pallidus** [L. *globus,* a round body + L. *pallidus,* pale] (Fig. 1.8). The caudate nucleus, the putamen, and the globus pallidus are the major nuclei of the **basal ganglia.** The details of their internal structure are considered in Chapter 8.

The Thalamus

The thalamus is the adult manifestation of the embryonic diencephalon. It is located rostral to the brainstem and lies in close association with the basal ganglia. The thalamus is a paired structure that contains several nuclei. Based on its embryological development, it is divided into three regions: the principal body of the **thalamus,** the **hypothalamus,** and the **epithalamus.** Although there is much anatomical detail associated with the thalamus, the discussion here will be limited to the external features that represent orientation landmarks.

When viewed from the dorsal aspect (Fig. 1.9), the principal body of the thalamus can be distinguished from the head of the caudate nucleus by a ridge that courses diagonally across it and medial to the internal capsule. This ridge is a fiber tract, the **stria terminalis** [L. *stria,* furrow + L. *terminalis,* terminal]. Medial and ventral to it lies the thalamus; lateral and dorsal is the caudate nucleus.

The adult structures derived from the epithalamus are the **habenula** [L. *habenula,* strap], the **stria medullaris,** and the **pineal body.** The habenula is located in the midline, at the posterior limit of the thalamus. It is a thin layer of tissue forming a roof over the posterior part of the third ventricle. Leaving the habenula is a ridge of fibers known as the stria medullaris, a tract that courses along the medial wall of the thalamus where it terminates in the septal nuclei, parts of the hypothalamus, and the anterior nuclear group of the

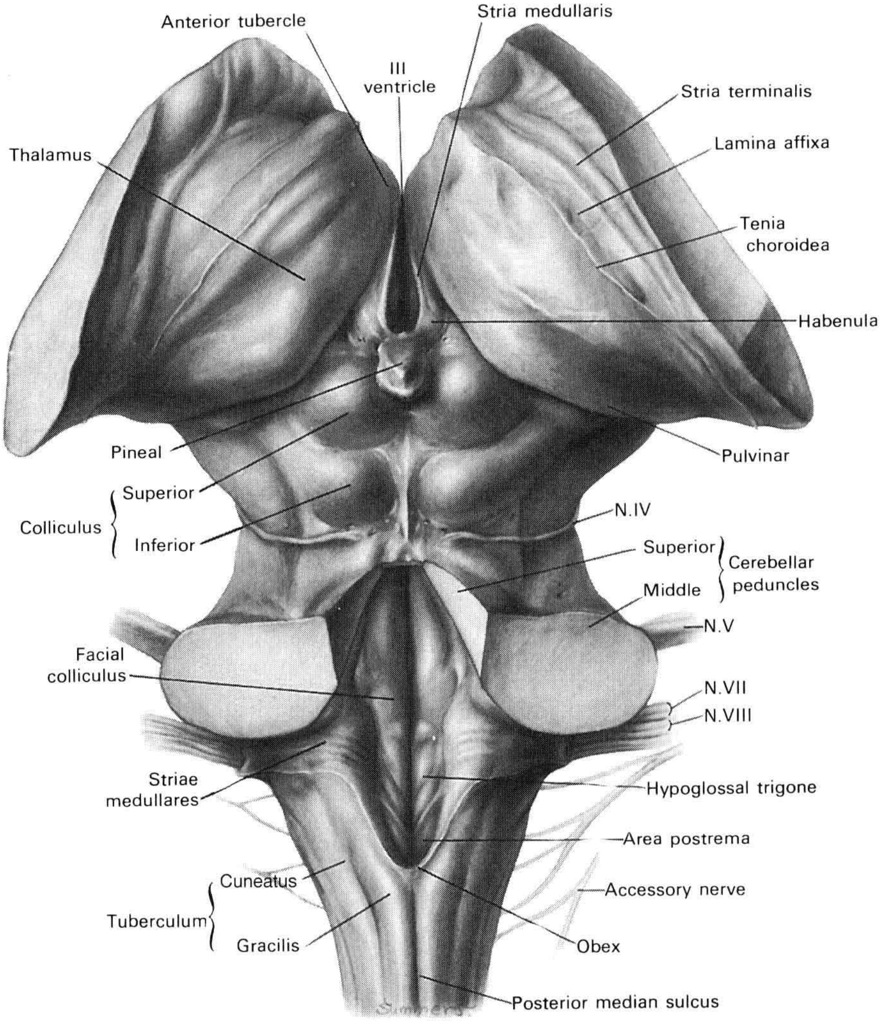

FIGURE 1.9.

A, Dorsal view of the brainstem.

principal thalamus. These nuclear structures are discussed elsewhere (see Chapter 12). In the midline, and merging with the habenula on either side, is the **pineal** body [L. *pineus,* like a pine].

The principal body of the thalamus is divided into a large number of nuclei serving sensory, motor, and cognitive functions. These nuclei are discussed in the various chapters dealing with these systems (see Chapters 5, 8, and 12). Two nuclei, the **medial geniculate** and the **lateral geniculate** nuclei, sometimes called the metathalamus, can be seen in gross dissection as bulges on the lateral surface of the thalamus (Fig. 1.9).

Viewed from the lateral aspect of the thalamus, one can see the **optic tract** (CN II) wrapped around the side of the cerebral peduncle and terminating at the lateral geniculate nucleus (Fig. 1.9). From the ventral aspect (Fig. 1.6), one can follow the left and right **optic tracts** rostrally to the point of their union in the **optic chiasm** [G. *chiasma,* two crossing lines (as in the Greek letter χ)]. From the optic chiasm, the **optic nerves** extend to the eyes. It is customary in neuroanatomy to describe collections of *axons in the central nervous system as tracts, fascicles, peduncles, or stria.* In the *pe-*