"以器官系统为中心"原版英文教材

SYSTEMS OF THE BODY

神经系统·第2版

The Nervous System

SECOND EDITION

BASIC SCIENCE AND CLINICAL CONDITIONS

Adina Michael-Titus
Patricia Revest
Peter Shortland

ELSEVIER

北京大学医学出版社

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北京大学医学出版社
Peking University Medical Press

图书在版编目（CIP）数据

神经系统=The Nervous System：第2版：英文/（英）米歇尔-提图斯（A. Michael-Titus）等主编．—影印本．—北京：北京大学医学出版社，2011.2

"以器官系统为中心"原版英文教材

ISBN 978-7-5659-0112-6

Ⅰ.①神… Ⅱ.①米… Ⅲ.①神经系统疾病—医学院校—教材—英文 Ⅳ.①R741

中国版本图书馆CIP数据核字（2011）第014351号

The Nervous System, second edition
Adina Michael-Titus, Patricia Revest, Peter Shortland
ISBN: 978-0-7020-3373-5

Authorized reprint edition from English edition published by the Proprietor.
978-981-272-308-6
981-272-308-0

Elsevier (Singapore) Pte Ltd.
3 Killiney Road, #08-01 Winsland Hose I, Sinagpore 239519
Tel: (65) 6349-0200, Fax: (65) 6733-1817
First published 2011
2011年初版

北京市版权局著作权合同登记号：图字：01-2011-1656

神经系统（第2版）

编　　写：Adina Michael-Titus, Patricia Revest, Peter Shortland
出版发行：北京大学医学出版社（电话：010-82802230）
地　　址：（100191）北京市海淀区学院路38号　北京大学医学部院内
网　　址：http://www.pumpress.com.cn
E - mail：booksale@bjmu.edu.cn
印　　刷：北京画中画印刷有限公司
经　　销：新华书店
责任编辑：冯智勇　　**责任校对**：何　力　　**责任印制**：张京生
开　　本：889mm×1194mm　1/16　　**印张**：21.75　　**字数**：695千字
版　　次：2011年4月第1版　2011年4月第1次印刷
书　　号：ISBN 978-7-5659-0112-6
定　　价：89.00元

出版说明

“以器官系统为中心”的医学教学模式是国际医学教育的趋势。本系列书是世界著名医药卫生出版集团爱思唯尔公司出版的一套“以器官系统为中心”的医学基础课程教材，共分为骨骼肌肉系统、心血管系统、呼吸系统、消化系统、泌尿系统、神经系统、内分泌系统七个分册。该套教材第1版出版后受到世界各地许多医学院校的欢迎，并被多家进行“以器官系统为中心”教学的医学院校选定为教材。第2版根据第1版出版后教师和学生的反馈意见，结合医学知识的更新进行了全新修订。在编写内容上，该系列教材强调基础与临床的整合。每一章节都是围绕着一个临床病例展开，通过对病人问题的呈现以及解决过程引出对相关知识的探究，从而使与器官系统结构、功能以及疾病相关的重要的基础医学知识得到了完善的整合。在版式安排上，图框中的病例资料与正文中的医学知识完美匹配，一步一步地激起读者的求知欲望。

当前，我国很多医学院校都在进行“以器官系统为中心”的医学课程教学改革，为了借鉴国外教材的经验，北京大学医学出版社通过版权引进影印出版了这套“SYSTEMS OF THE BODY”原版英文教材。该系列书可以作为医学院校“以器官系统为中心”教学的教材和教学参考书，也可以作为医学院校进行英语授课的教材或供学生自学使用。

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The diseases of the nervous system represent one of the most important challenges in modern medicine. Medical schools worldwide have adopted various strategies in the teaching of neuroscience. One of the more recent approaches combines anatomy, physiology and pharmacology, in order to achieve an integrated view of the various pathologies. The problem-based learning method in medicine is based on this concept of integration.

This book is part of the Systems of the Body series, which has been designed to provide a teaching tool for medical curricula that use problem-based learning. The aim of our book is to cover the basic science required to understand the structure and function of the nervous system, and its major pathologies, at a level appropriate to medical students in the first years of training. The volume comprises two parts. The early chapters offer an introduction to the general organization of the nervous system, and the cellular and molecular mechanisms that govern its function. A separate chapter is devoted to the clinical examination of the nervous system. The later chapters, which form the main body of the book, are built around clinical cases. The chapters start with clinical scenarios, which prompt an exploration of specific issues, thus allowing us to introduce and discuss the knowledge that is required for the diagnosis and treatment of the conditions presented. To reflect the rapid pace of research in neuroscience, the information in the second edition has been updated throughout the text, and figures modified as appropriate.

Our experience of teaching medical students guided us throughout the writing of this text, and we tried to present complex concepts in an accessible and clear manner. Our wish was not only to present the facts, but also to increase the students' awareness of the many unresolved issues in neuroscience. It is our hope, therefore, that this book will not only assist students in the learning process, but also stimulate their interest and enthusiasm for the fascinating field of neuroscience.

We would like to express our thanks to the various people who have supported us throughout the writing of this book.

Michael Parkinson encouraged us to write this volume, and Lynn Watt provided guidance in the initial phases of the project. Very special thanks go to Dr Lulu Stader, who helped us, cajoled us and kept us on track, so that the work could be completed. Her expertise, understanding and support, and her sense of humour, were invaluable.

Many thanks are due to our colleagues, Dr Gregory Michael, Dr Julian Millar and Dr Sadashiv Karanth, who provided some material and made comments on parts of the manuscript, and to Dr Joshi George, who reviewed the Clinical Examination chapter.

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ADDICTION 301

1

ORGANIZATION OF THE NERVOUS SYSTEM

Chapter objectives

After studying this chapter you should be able to:

1. Describe the basic organization of the peripheral and central nervous systems.
2. Name and identify the major nervous system structures and describe their primary functions.
3. Describe the organization and functions of the autonomic nervous system.

Introduction

The nervous system, which consists of the brain, spinal cord and peripheral nerves, is a highly specialized and complex structure. It is an information-processing system that regulates all the physiological functions of the organism. In addition, the nervous system performs unique functions that operate independently of other systems in the body. These underlie consciousness, memory, rationality, language, and the ability to project our mental images forwards or backwards in time. Representations of the external world are transmitted, transformed and manipulated by the nervous system to subsequently affect behaviour. Thus, the nervous system has four important functions:

1. sensory (gathering of information from the external environment)
2. integrator (of information from all sources for assessment)
3. effector (to produce a motor response)
4. internal regulator (homeostasis for optimum performance).

The net results of all these functions are as follows: first, the creation of a sensory perception of the external world; second, behaviour; and finally, the creation of knowledge that can be used to guide future behaviour in response to changes in the surrounding environment.

In order to appreciate how the nervous system produces behaviour, it is necessary to understand how it is organized functionally and anatomically. The experience of examining a brain is very much like the experience of buying a car. Before buying a car, you inspect it and then take it for a test drive to make sure that it operates normally and runs smoothly without faults. Then you open up the bonnet to look at the engine. Unless you happen to be a trained mechanic or have an interest in car engines, you might be able to name a few parts, e.g. the radiator, the battery and the fan belt, but not the rest of the mass of wires, spark plugs and assorted boxes. Moreover, knowledge of the name does not always indicate what the function is, or how all the different parts combine to burn petrol to make the car run. It is the same with the nervous system; you may be able to name some of the parts, such as the cortex, cerebellum and brainstem, and have a rough idea of what some of the different parts do, but have little idea of how they accomplish a task such as reading this sentence. And when the car breaks down, we call the automobile rescue services. When the nervous system breaks down or misfires, we call in the neurologists, neurosurgeons or psychiatrists.

Although the anatomy of the nervous system appears complex and daunting, its organization is governed by a set of relatively simple developmental, organizational and functional rules that bring order to it. The functional rules are summarized in Table 1.1.

The aim of this chapter is to provide a functional overview of the neuroanatomy of the brain, spinal cord and nerves. To do this, it is necessary to consider the basic parts of the nervous system, to identify what they do, and how they are related. Finally, we can see how the different parts interact, using the principles outlined in Table 1.1, to produce behaviour.

Table 1.1 Principles underlying the functioning of the nervous system

Behaviour is produced by processing of information in a sequence of 'in → integrate → out'
Separate sensory and motor divisions exist throughout the nervous system
The nervous system has multiple levels of function
The nervous system is organized both in parallel and in series
Most neural pathways relaying information decussate from one side of the central nervous system to the other
The nervous system regulates activity through excitation and inhibition
There is both symmetry and asymmetry in brain anatomy and function
Some of the functions of the brain are located in specific regions of the brain, while others are distributed

The nervous system comprises two parts: the peripheral nervous system (PNS) and the central nervous system (CNS). These two systems are anatomically separate but are functionally interconnected and integrated (Fig. 1.1). The PNS consists of nerve fibres that transmit specific sensory and motor information to the CNS, which comprises the spinal cord, brainstem and brain. The CNS is housed within the bony structures of the vertebral canal and skull, for protection. Additional mechanical buffering protection of the CNS is afforded by the surrounding meninges and ventricular system.

Overview of brain anatomy

The CNS comprises six anatomical regions: the cerebral cortex, the diencephalon (thalamus and hypothalamus), the midbrain, the pons and cerebellum, the medulla, and the spinal cord (Fig. 1.2). The best way to understand the anatomy is to look at the external and internal topography, to identify anatomical structures and their relationships, and then to define the functions of the identified structures.

Meninges

If we open the skull and look inside, the first thing seen is the membranes that cover the brain, called meninges. These membranes surround and protect the CNS. There are three layers: the dura mater, arachnoid and pia mater. The dura mater forms folds that separate different brain regions from each other and demarcate anatomical

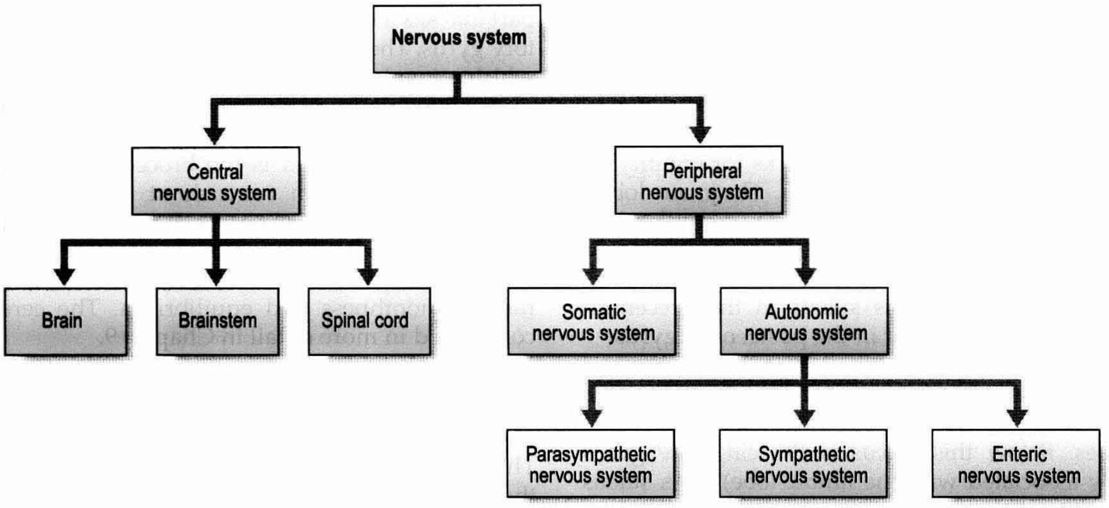


Fig. 1.1 Overview of the anatomical organization of the nervous system.

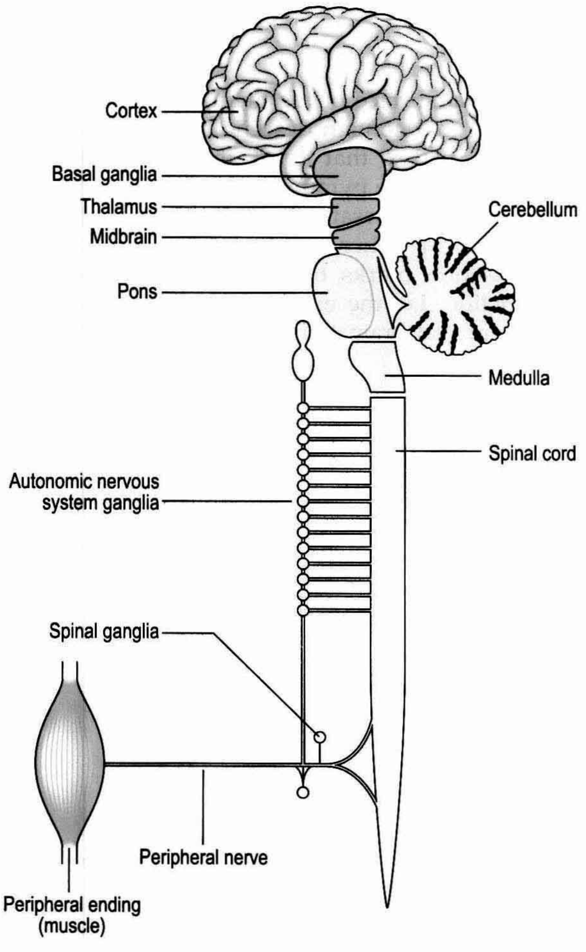


Fig. 1.2 Major parts of the nervous system. Light shading: structures of the supratentorial level. Dark shading: structures of the posterior fossa level. No shading: structures of the spinal level.

boundaries within the skull cavity. These layers are described in more detail in Chapter 12.

Cortical lobes

When the meninges are removed, one can observe the gross anatomy of the CNS. Anatomically, the cortex is described according to lobes that are named in relation to skull bones. Thus, there are four lobes visible from the outside of the brain: the occipital, temporal, parietal and frontal lobes. In addition, there is one other lobe that cannot be seen from the outside of the brain: the limbic lobe. It comprises the medial portions of the frontal, parietal and temporal lobes, forming a rim around the corpus callosum (a fibre tract that connects the two cortical hemispheres). Another cortical area, the insula, lies buried in the medial wall of the lateral fissure, overlain by parts of the frontal, parietal and temporal lobes; it is functionally associated with the limbic lobe. The lobes are divided into regions that are associated with specific functions (see Table 1.2).

Surface features: sulci and gyri

The surface of the cortex is highly convoluted and is subdivided into fissures (deep grooves), gyri (elevated folds; singular = gyrus) and sulci (singular = sulcus; shallow grooves between folds). The folds massively increase the surface area of the cortex. The longitudinal fissure separates the two cortical hemispheres, and the lateral fissure (of Sylvius) separates the temporal lobe from the parietal and frontal lobes. The central sulcus and the parieto-occipital sulcus define the boundaries of the frontal and parietal, and parietal and occipital, lobes respectively. On the lateral surface of the hemispheres, the boundaries between parietal, occipital and temporal lobes are established by continuing the line of the parieto-occipital sulcus downwards, to the inferior surface of the hemisphere, and the line of the lateral fissure backwards to meet this line (Fig. 1.3B).

The pattern of sulci and gyri is extremely variable, and defining even the major sulci and gyri is not easy. In general, the surface of each lobe can be divided into three gyri by two sulci. The sulci provide landmarks for identifying lobes and functional areas of the brain. The main lobes, gyri and sulci are shown in Figure 1.3. The central sulcus marks the position of two important functional areas: primary somatosensory cortex and primary motor cortex. The latter lies anterior to this sulcus in the precentral gyrus; the former lies posterior in the postcentral gyrus.

On the medial surface (see Figs 1.3C and 1.5), the cingulate sulcus follows approximately the curvature of the corpus callosum, extending through both the frontal and parietal lobes. Below this sulcus is the cingulate gyrus (functionally associated with the limbic lobe). This sulcus terminates by passing upwards to form a sulcus that continues onto the lateral surface of the hemisphere as the postcentral sulcus (Fig 1.3B). The central sulcus is usually the sulcus immediately anterior to this sulcus (on the lateral surface). The gyrus in between these two sulci is the postcentral gyrus, which contains the primary somatosensory cortex. Anterior to the point where the cingulate sulcus crosses (to the lateral surface of the brain) is the paracentral lobule, which contains the lower limb primary motor and somatosensory cortical function regions. The gyri (lingular and cuneus) either side of the calcarine sulcus in the posterior part of the brain are associated with vision.

On the inferior surface (Fig. 1.3A) of the temporal lobe, the most medial gyrus is the parahippocampal gyrus, which expands at its anterior end to form the bulbous, hook-like uncus. These are evolutionarily old parts of the cerebral cortex and are concerned, in part, with the olfactory (smell) system and with memory. In the orbitofrontal cortex (the part that sits above the orbit in the skull) is located the olfactory gyrus. These structures form part of the limbic system, which is involved in emotional processing and perception.

Also visible from the underneath of the brain are the cerebellum and brainstem, which together form the hindbrain. The cerebellum is the broccoli-like structure that lies above the fourth ventricle at the back of the head and below the occipital cortex. It is the largest part of the hindbrain. The function of the cerebellum is coordination of movements. This includes muscle tone, movement range, smoothness and equilibrium. The cerebellum is considered in more detail in Chapter 9.

Brainstem

The brainstem is located within the posterior fossa of the skull and consists of three parts: midbrain, pons and medulla. These relay information to and from the periphery to higher centres such as the cortex and cerebellum. The brainstem also receives direct input from the cranial nerves. The functions of these nerves and the internal anatomy of the brainstem are described in Chapter 6.

Medulla

On the ventral surface of the medulla are the pyramids (see Fig. 6.1) that contain descending motor fibres from the cerebral cortex that form the corticospinal tract (CST), also called the pyramidal tracts of the spinal cord. The pyramidal decussation is where most of the CST fibres cross to the other side to become the lateral CST. The decussation marks the location of the spinomedullary junction, i.e. the end of the spinal cord and the beginning of the brainstem. Lateral to the rostral part

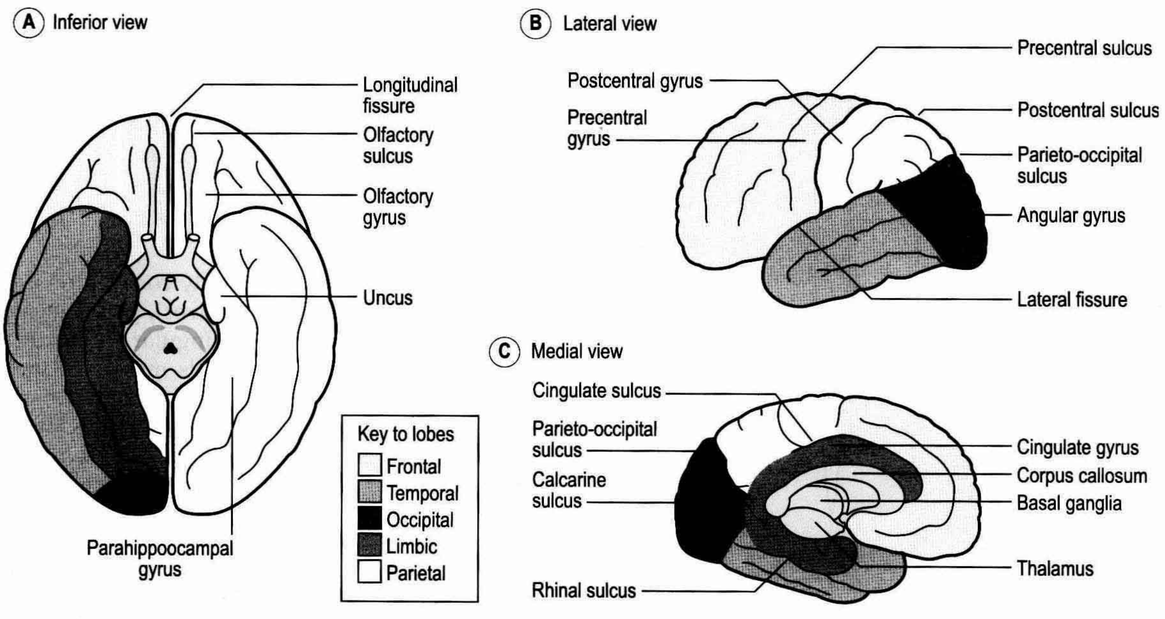


Fig. 1.3 Main gyri, sulci, fissures and lobes of the brain.

of the pyramids are two oval swellings that identify the inferior olivary nuclei (ION), which are functionally associated with the cerebellum. They provide a surface landmark for the emergence of cranial nerves IX–XII; nerve XII emerges between the ION and the pyramids, whereas nerves IX–XI emerge laterally to the ION.

On the dorsal surface of the brainstem, the medulla consists of two parts, the open and closed medulla, due to the emergence of the central canal from the spinal cord opening into the fourth ventricle. The point at which this occurs is called the obex. The closed part of the medulla shows a pair of gracile and cuneate tubercles that mark the position of the gracile and cuneate nuclei (see Fig. 6.1), which transmit sensory information to higher brain centres.

Pons

The ventral pons has a transversely ridged appearance, with a shallow groove running along the midline called the basilar sulcus, which contains the basilar artery. The ridged appearance is due to fibres entering the cerebellum from the nerve cells in the pons, which, in turn, are the recipients of a major input from the cerebral cortex (see Fig 6.1). The trigeminal nerve is the only nerve to emerge from this ridged region, while cranial nerves VII and VIII exit at the cerebellopontomedullary angle. The position of cranial nerves VI–VIII identifies the pontomedullary junction on the ventral surface.

The pons is sharply demarcated both rostrally and caudally from the other parts of the brainstem. The open medulla and pons together form the floor of the fourth ventricle, which is diamond-shaped. The closure of the rostral part of the fourth ventricle to form the cerebral aqueduct and the cerebral peduncles demarcates the transition from pons to midbrain.

Midbrain

The midbrain (see Fig. 6.1) is short, and very little of it can be seen in the undissected brain. Ventrally, the cerebral peduncles are located lateral to two small circumscribed mounds, the mamillary bodies (part of the hypothalamus). The peduncles are large bundles of fibres descending from the motor cortex to the brainstem and spinal cord, and comprise chiefly the pyramidal and corticopontine fibre systems. The dorsal surface of the midbrain is called the tectum and has two paired swellings, the inferior and superior colliculi, which are involved in auditory and visual reflexes. These are buried beneath the overlying cerebral hemispheres. Two cranial nerves exit the midbrain, cranial nerve III at the midbrain–pons junction and cranial nerve IV on the dorsal surface.

Spinal cord

The spinal cord connects the brain to the PNS. It is the part of the CNS located outside the skull, below the foramen magnum but within the vertebral column. The spinal level of the nervous system extends from the skull to the sacrum. The spinal cord receives input from the periphery, relays it to the brain and sends response signals back to the periphery. The spinal cord is not segmented; rather, the distribution of the peripheral nerve spinal roots gives it a functional segregation. The details of spinal cord function are described in Chapter 4. The spinal cord consists of grey matter and white matter, like the brain (except that in the spinal cord the white matter is on the outside). The grey matter contains cells and is surrounded by white matter that contains mainly bundles of axons ascending and descending in the spinal cord.

Internal anatomy of the brain

The easiest way to see the various anatomical structures deep inside the brain is to cut it open. However, what is seen depends on the plane of section; the same structures look different in different planes (see Box 1.1).

Sagittal sections

If the brain is split in two at the midline, cutting along the sagittal fissure, the cerebrum is divided into its two hemispheres, as shown in Figure 1.5. In this plane, below the corpus callosum we can see most of the deep (subcortical) structures of the brain, the thalamus, the hypothalamus and the ventricular system. Moving laterally in this plane, adjacent sections would also reveal the appearance of the basal ganglia nuclei that are located on top of the thalamus and form part of the lateral walls of the ventricular system. The basal ganglia are more easily viewed in frontal and horizontal sections (see Figs 1.7 and 1.10). In the upper part of Figure 1.5, they are obscured by a thin membranous sheet, the septum pellucidum (which is torn in this specimen). Most of these structures can be seen in the MRI image shown in the lower part of Figure 1.5.

Coronal sections

Frontal (coronal) sections are the easiest plane to visualize, because their orientation is such that viewing them is just like looking at another person face-on. When sectioning from front to back, the very first section seen in a coronal series would be just the tips of the frontal lobes, which are located right behind the forehead. In Figure 1.6 we have moved backwards a little, to the first section containing internal structures. In these sections, the white matter (axons) appears white and the grey matter (cell bodies) appears grey. The first thing to notice is the corpus callosum. This major pathway connects the two hemispheres and serves as a useful landmark, because it appears in all coronal sections in which deep structures are present.

Below the corpus callosum are the front ends of the two lateral ventricles, separated by the septum pellucidum. The masses of grey matter that form the lateral walls of the

Box 1.1 Brain topography

Anatomical descriptions of images and tissue sections are based on four anatomical planes, sagittal, horizontal, transverse and median (Fig. 1.4). The horizontal (axial) plane is a plane across the brain that would be horizontal if the patient were standing up. The median plane is one that slices the brain vertically along the midline into two symmetrical halves; sagittal sections are vertical planes through the brain parallel to the median plane. The coronal (frontal) plane is one slicing the brain vertically across (e.g. from ear to ear).

In addition, structures towards the front of the brain are termed anterior (or rostral) and those towards the back are posterior (or caudal). Those towards the top of the brain are termed superior and those towards the bottom are termed inferior. Structures located laterally are further away from the midline, and those located medially are nearer the midline.

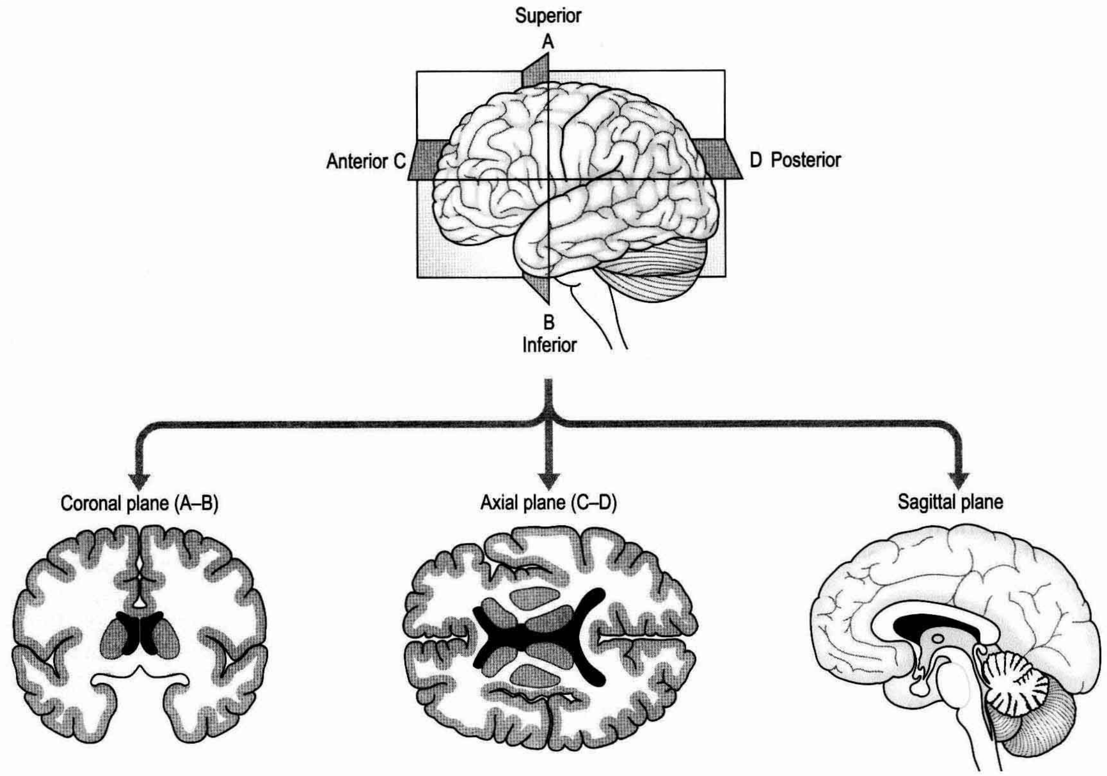
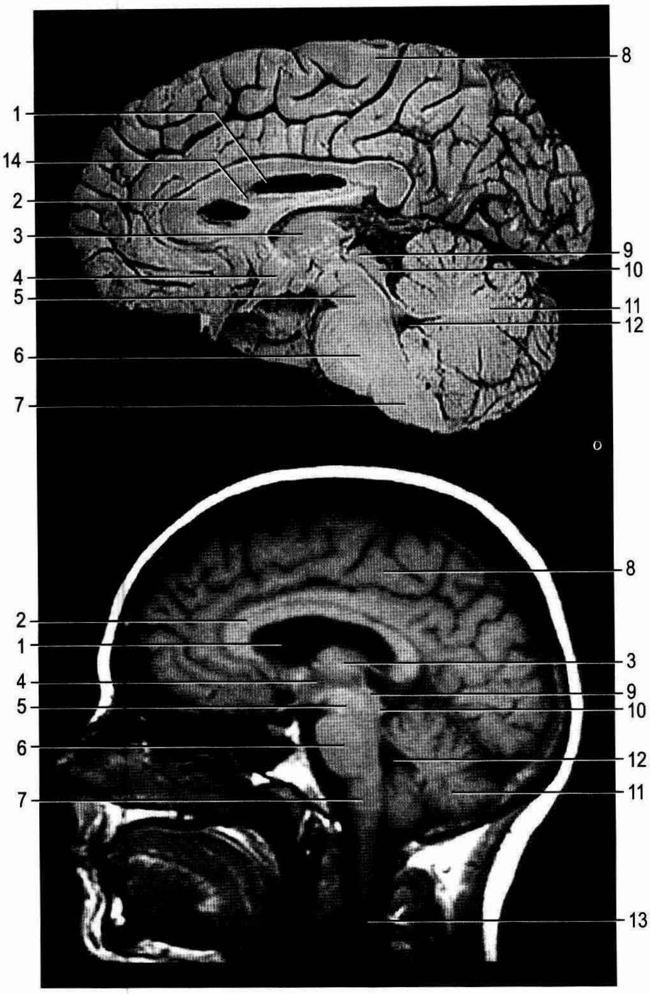


Fig. 1.4 Anatomical planes of section. Shading: black, ventricles; grey, grey matter; yellow, white matter.

lateral ventricles are the caudate nuclei (part of the basal ganglia). The rule for identifying them is simple: if the lateral ventricles are visible, so is the caudate. This applies throughout the curved extent of the lateral ventricles, as the caudate follows them the whole way.

The caudate appears to be joined by threads of grey matter to another nucleus, the putamen. These two nuclei are almost always divided by a band of axons called the internal capsule, which is a major pathway for connections between the thalamus and the cortex. In the rostral brain, these two nuclei are continuous at the base, so that in reality the caudate and the putamen are a single nucleus, divided in half by the internal capsule; hence they are commonly called the striatum. Early anatomists did not realize this, so they were named separately, and the small ventral bridge below the internal capsule which connects them was named the nucleus accumbens. The nucleus accumbens and the septal nuclei are associated with conscious 'reward' and motivation and are part of the limbic system. These structures are involved in the mediation of the effects of addictive drugs such as cocaine, heroin and amphetamines.

In the next most caudal section, shown in Figure 1.7A, the nucleus accumbens has disappeared and the caudate and putamen are no longer connected. The caudate nucleus is decreased in size, and medial to the putamen



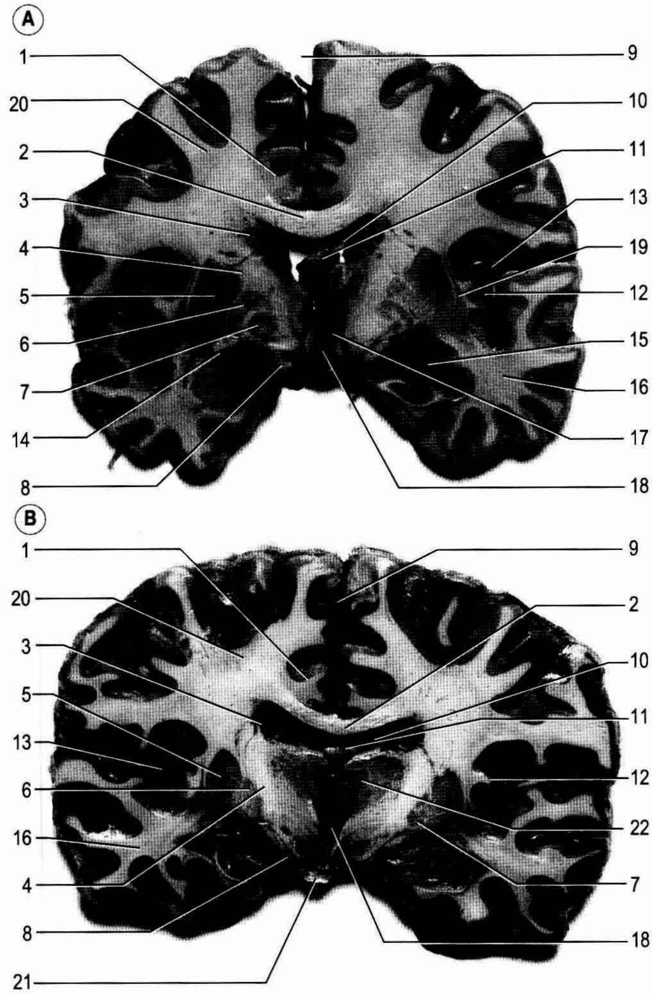
1. Lateral ventricle.
2. Corpus callosum.
3. Thalamus.
4. Hypothalamus.
5. Midbrain.
6. Pons.
7. Medulla.
8. Paracentral lobule.
9. Superior colliculus.
10. Inferior colliculus.
11. Cerebellum.
12. Fourth ventricle.
13. Spinal cord.
14. Septum pellucidum.

Fig. 1.5 Midsagittal section of the brain shown in a gross specimen (top) and at the equivalent level on a magnetic resonance imaging scan (bottom).

1. Frontal lobe.
2. Lateral ventricle.
3. Septum pellucidum.
4. Anterior limb of internal capsule.
5. Temporal lobe.
6. Septal nuclei.
7. Longitudinal fissure.
8. Cingulate gyrus.
9. Corpus callosum.
10. Caudate nucleus.
11. Putamen.
12. Nucleus accumbens.
13. Hypothalamus.
14. Third ventricle.

Fig. 1.6 Coronal section of the brain.

there is the emergence of a new set of basal ganglia nuclei, the globus pallidus external (GPe) and internal (GPi). We can clearly see the diagonal openings that connect the lateral ventricles with the midline third ventricle. The septum here is very small, and suspended from it like two pieces of fruit are tracts called the fornices (fornix for one tract). The third ventricle is below the fornices. The fornix connects the mamillary body to the hippocampus (in the temporal lobe). Its inferior part can be seen adjacent to the third ventricle above the hypothalamus. Below the hypothalamus at the base of the brain is the optic tract. Below and between the putamen and GPe and just above the temporal lobe is a white matter tract called the anterior commissure, which connects the temporal lobes of each hemisphere. In the



1. Cingulate gyrus.
2. Corpus callosum.
3. Caudate nucleus.
4. Internal capsule.
5. Putamen.
6. Globus pallidus external.
7. Globus pallidus internal.
8. Optic tract.
9. Longitudinal fissure.
10. Lateral ventricle.
11. Fornix.
12. Insula cortex.
13. Lateral fissure.
14. Anterior commissure.
15. Amygdala.
16. Temporal lobe.
17. Hypothalamus.
18. Third ventricle.
19. Claustrum.
20. Frontal lobe.
21. Mamillary bodies.
22. Thalamus.

Fig. 1.7 Coronal section of the brain.

medial part of the temporal lobe is a circumscribed region of grey matter, the amygdala. The amygdala is a specialized form of cortex, and is part of the limbic system. It deals with the emotional significance of experiences. The insula cortex is also visible at this level. The insula appears to play a role in language and in the integration and perception of sensory stimuli such as pain and is part of the limbic system. Between the insula and putamen is a nucleus called the claustrum. The function of the claustrum is unclear but it has connections with the hippocampus, amygdala, caudate nucleus, premotor, prefrontal, auditory and visual cortices, suggesting a role in integration of multiple modalities to contribute to perception. The claustrum is separated from the insula by the extreme capsule and from the putamen by the external capsule.

Moving further caudally, (Fig. 1.7B), another major nucleus appears: the thalamus. The thalamus is a heterogeneous group of nuclei that are the gatekeepers for any information passing to and from the cerebral cortex. The thalami are located on either side of the slit-like third ventricle. This provides another anatomical rule: if the third ventricle is visible, so is the thalamus. The thalamus is located medial to the internal capsule (posterior limb), while the putamen and globus pallidus remain lateral to it; this relationship is always preserved and is more easily seen in horizontal sections. The ventral surface of the pons has also been cut, showing the transverse cerebello-pontine fibres. The two swellings above it are the mamillary bodies at the base of the midbrain.

In the next section (Fig. 1.8), the globus pallidus and putamen have disappeared. The caudate nuclei are very small and the thalami are larger. A new structure visible here in the medial temporal lobe, shaped like a sea-horse, is the hippocampus. At this level, more of the ventral surface of the brainstem has been sectioned. Medial to the hippocampus on either side are diagonally running white matter tracts that pass through the midbrain, pons and medulla. These are the pyramidal tracts. Also visible in the midbrain region is the substantia nigra, which has been cut obliquely.

Figure 1.9 is the last section of this series and now a lot has changed. The posterior part of the left lateral ventricle is visible as a long diagonal slit comprising the posterior and inferior horns (and associated choroid plexus). The lateral ventricle, like many other structures in the brain, curves back and loops under itself like a big C. The hippocampus, which is involved in memory formation, is clearly