CHAPTER

8

Cerebrum

Knowledge is better than wealth. You have to look after wealth, knowledge looks after you.
Our life is what our thoughts make it
—M Aurelius

INTRODUCTION

The cerebrum (Latin *brain*) is the largest part of the brain. It is also known as pallium. It occupies anterior, middle cranial fossae and the supratentorial part of the posterior cranial fossa (Figs 8.1a, b; 8.2 to 8.5). It is made up of outer grey matter and inner white matter and some neuronal masses called basal ganglia within the white matter. Besides this each hemisphere contains a cavity called lateral ventricle.

There is free flow of information in the central nervous system; between two hemispheres through the commissural fibres; between various parts of one hemisphere through the association fibres and between upper and lower parts through the projection fibres. Internal capsule contains lots of fibres packed in its "limbs". It is supplied by the "end artery". The rupture of "end artery" may cause the "end" of the human being concerned, if not treated properly.

DISSECTION

Keep the cerebrum in a position so that the longitudinal fissure faces superiorly. Identify the convex strong band of white matter, the corpus callosum, binding parts of the medial surfaces of the two cerebral hemispheres. Define splenium as the thick rounded part of corpus callosum (Fig. 8.3).

Divide the corpus callosum in the median plane starting from the splenium towards the trunk, genu and ostrum. Inferior to the trunk of corpus callosum extend he incision into the tela choroidea of the lateral and hird ventricles, and the interthalamic adhesion onnecting the medial surfaces of two thalami.

Identify the thin septum pellucidum connecting the ferior surfaces of corpus callosum to a curved band white matter—anterior column of the fornix. Look for the anterior commissure just at the anterior end of the anterior column of fornix.

Turn the brain upside down and identify optic chiasma (Fig. 8.4). Divide the optic chiasma, anterior communicating artery, infundibulum and a thin groove between the adjacent mammillary bodies, posterior cerebral artery close to its origin. Carry the line of division around the midbrain to join the two ends of the median cut. Separate the right and the left cerebral hemispheres.

In the two hemisphere, identify the three surfaces, four borders, three poles. Identify the central sulcus, posterior ramus of lateral sulcus, parieto-occipital sulcus and preoccipital notch. Join parieto-occipital sulcus to preoccipital notch. Extend the line of posterior ramus of lateral sulcus till the previous line. Now demarcate the four lobes of the superolateral surface of each cerebral hemisphere (Figs 8.1a and b).

Strip the meninges from the surfaces. Identify the vessels on the surfaces of hemisphere. Demarcate the main sulci and gyri on the superolateral surface, medial surface and inferior surface of hemisphere.

Make thin slice through the part of the calcarine sulcus, posterior to its junction with the parieto-occipital sulcus. Identify the stria running through it. On cutting series of thin slices try to trace the extent of visual stria.

Features

The cerebrum is made of two cerebral hemispheres which are incompletely separated from each other by the median *longitudinal fissure*. The two hemispheres are connected to each other across the median plane by the corpus callosum. Each hemisphere contains a cavity, called the lateral ventricle. The surface area of cerebrum is 2000 cm.^{2}

Cerebral Sulci and Gyri

Cerebral cortex is folded into gyri (Greek *circle*) which are separated from each other by sulci. This pattern increases the surface area of the cortex. In human brain, the total area of the cortex is estimated to be more than 2000 cm^2, and approximately two-thirds of this area is hidden from the surface within the sulci. The pattern of folding of the cortex is not entirely haphazard. It is largely determined by the differential growth of specific functional areas of the cortex, because many of the sulci bear a definite topographical relation to these areas. The formation of sulci in the intrauterine life begins from 5th–6th month and ends almost at the end of ninth month.

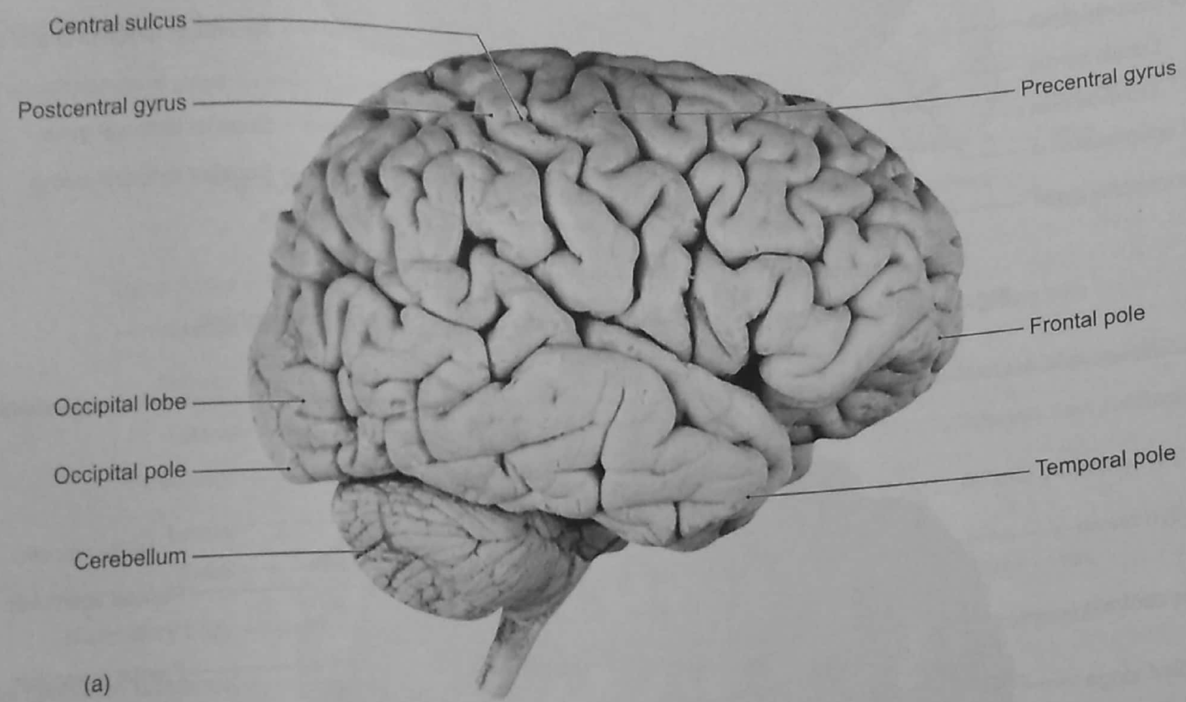
CEREBRAL HEMISPHERE

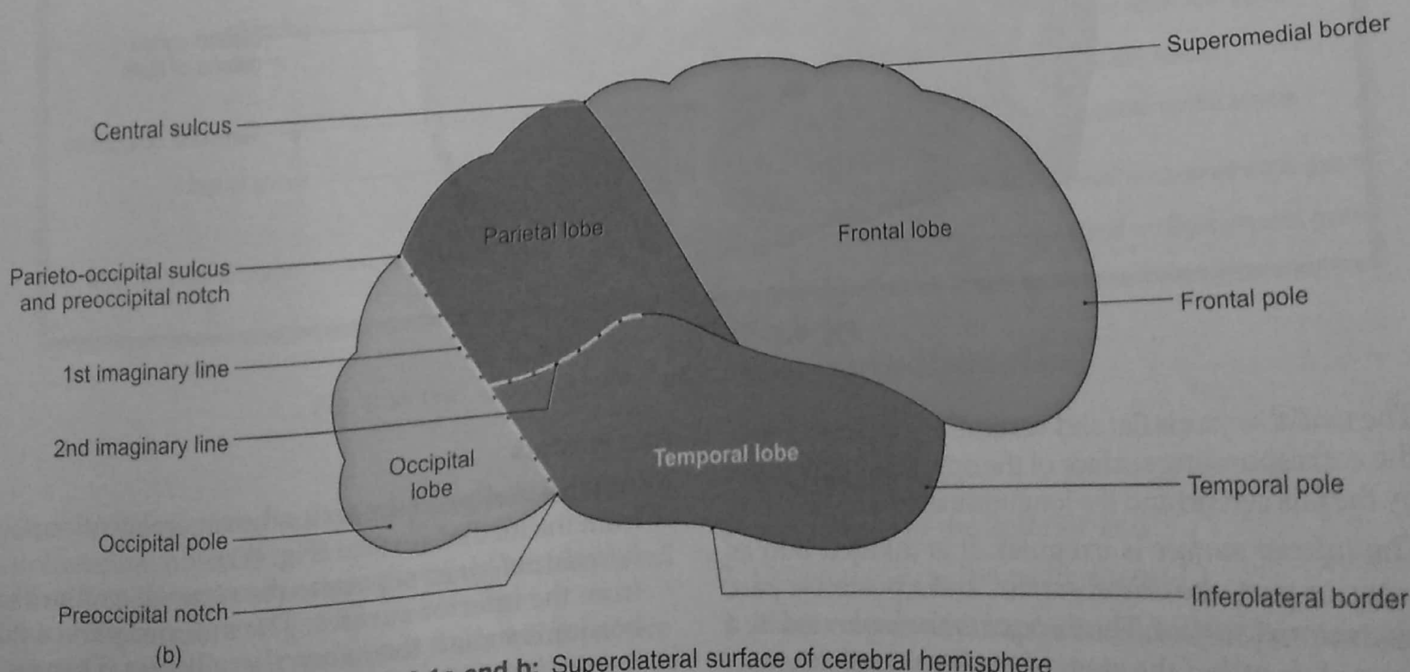
EXTERNAL FEATURES

Each hemisphere has the following features:

Three Surfaces

1 The *superolateral surface* is convex and is related to the cranial vault (Figs 8.1a and 8.2).





Figs 8.1a and b: Superolateral surface of cerebral hemisphere

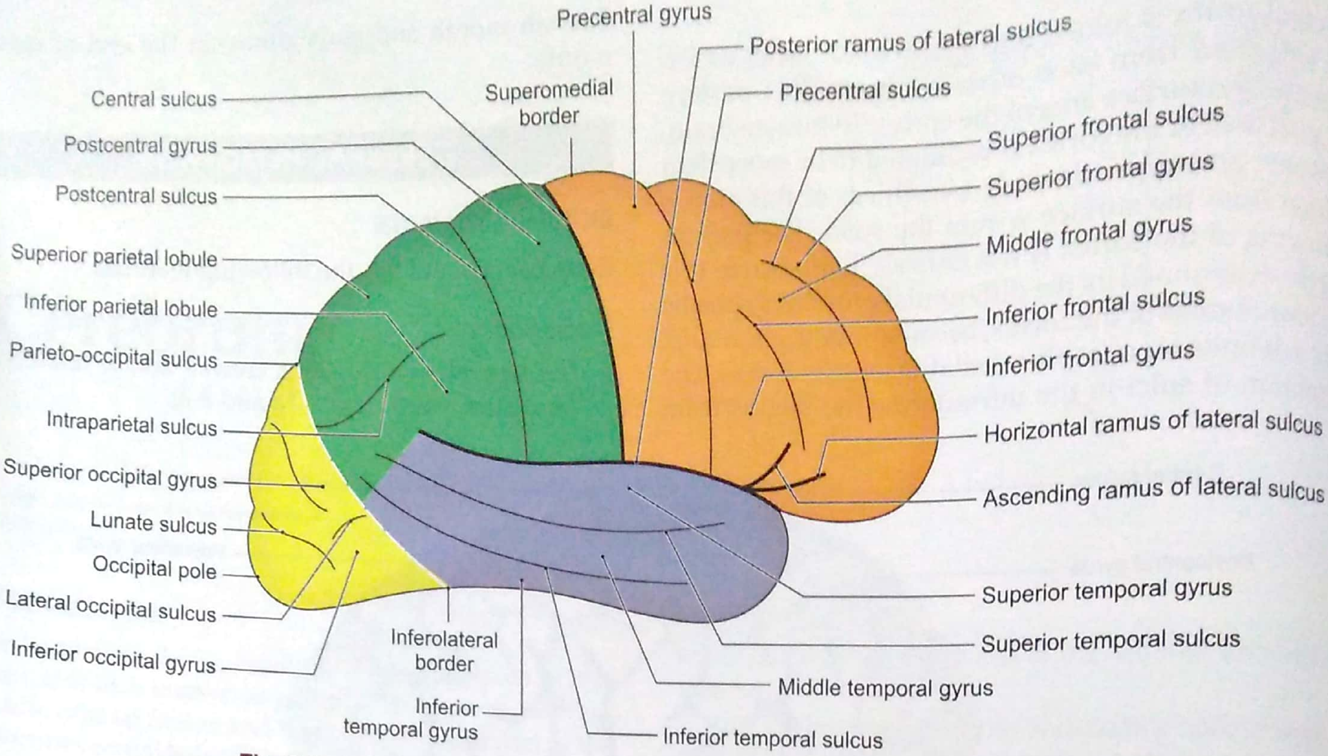


Fig. 8.2: Sulci and gyri on superolateral surface of right cerebral hemisphere

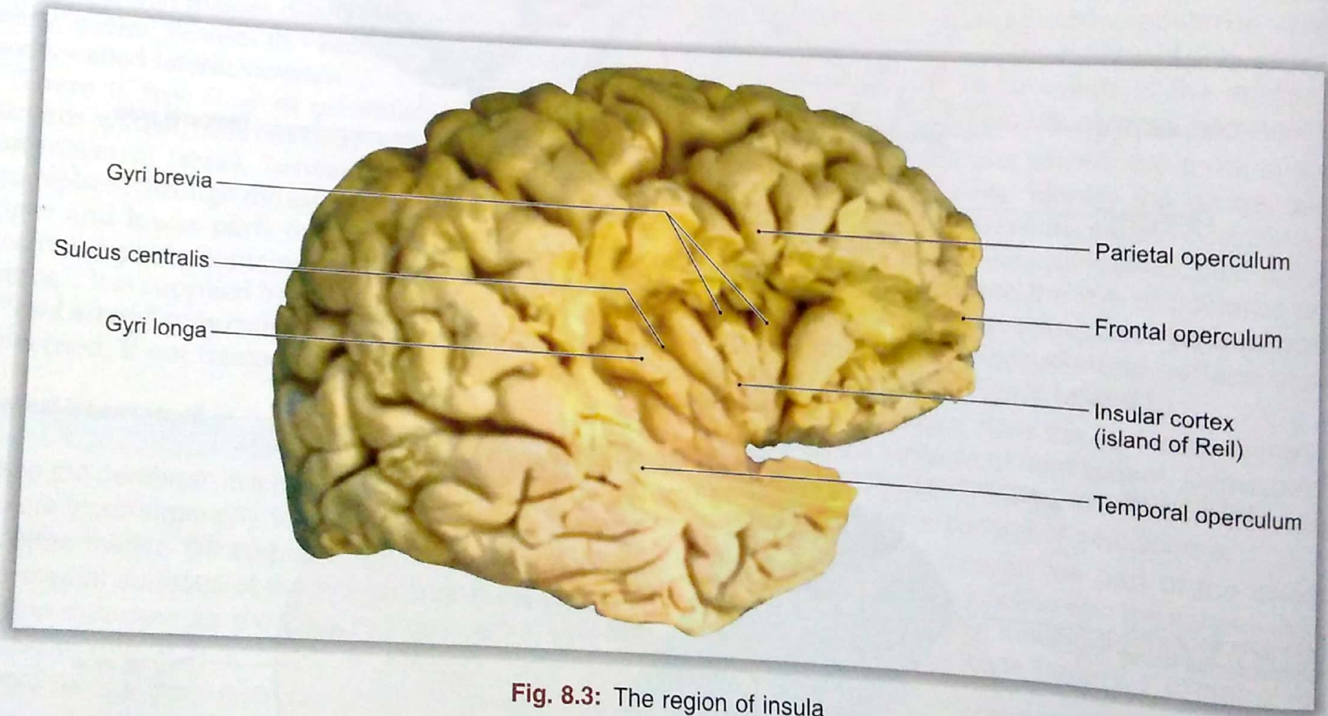


Fig. 8.3: The region of insula

2 The *medial surface* is flat and vertical. It is separated from the corresponding surface of the opposite hemisphere by the falx cerebri and the longitudinal fissure (Fig. 8.3).

3 The *inferior surface* is irregular. It is divided into an anterior part, the *orbital surface*, and a posterior part, the *tentorial surface*. The two parts are separated by a deep cleft called the stem of the lateral sulcus.

Four Borders

1 *Superomedial border* separates the superolateral surface from the medial surface (Fig. 8.1).

2 *Inferolateral border* separates the superolateral surface from the inferior surface. The anterior part of this border is called the *superciliary border*. There is a depression on the inferolateral border situated about

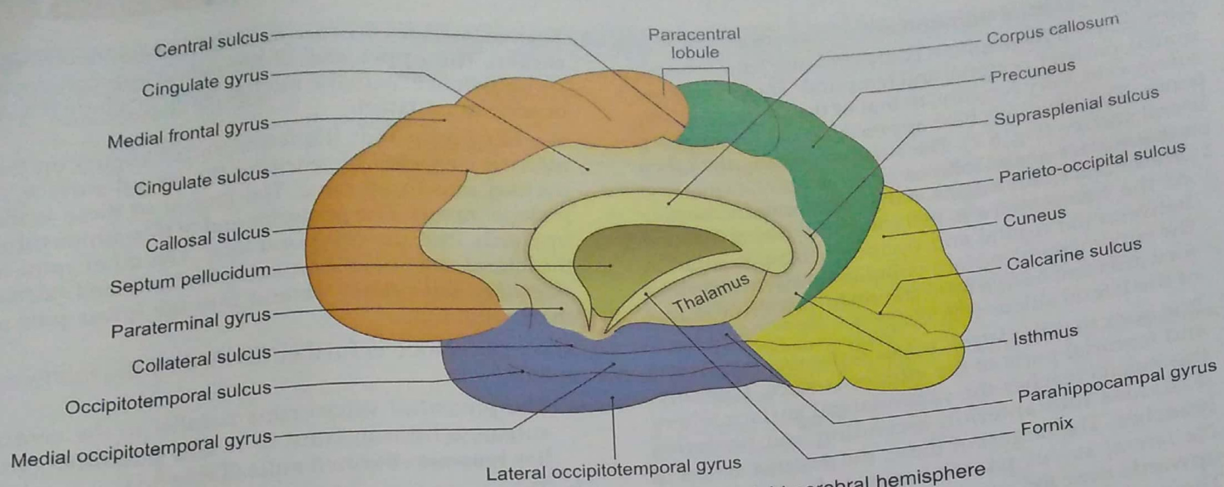


Fig. 8.4: Sulci and gyri on the medial surface of right cerebral hemisphere

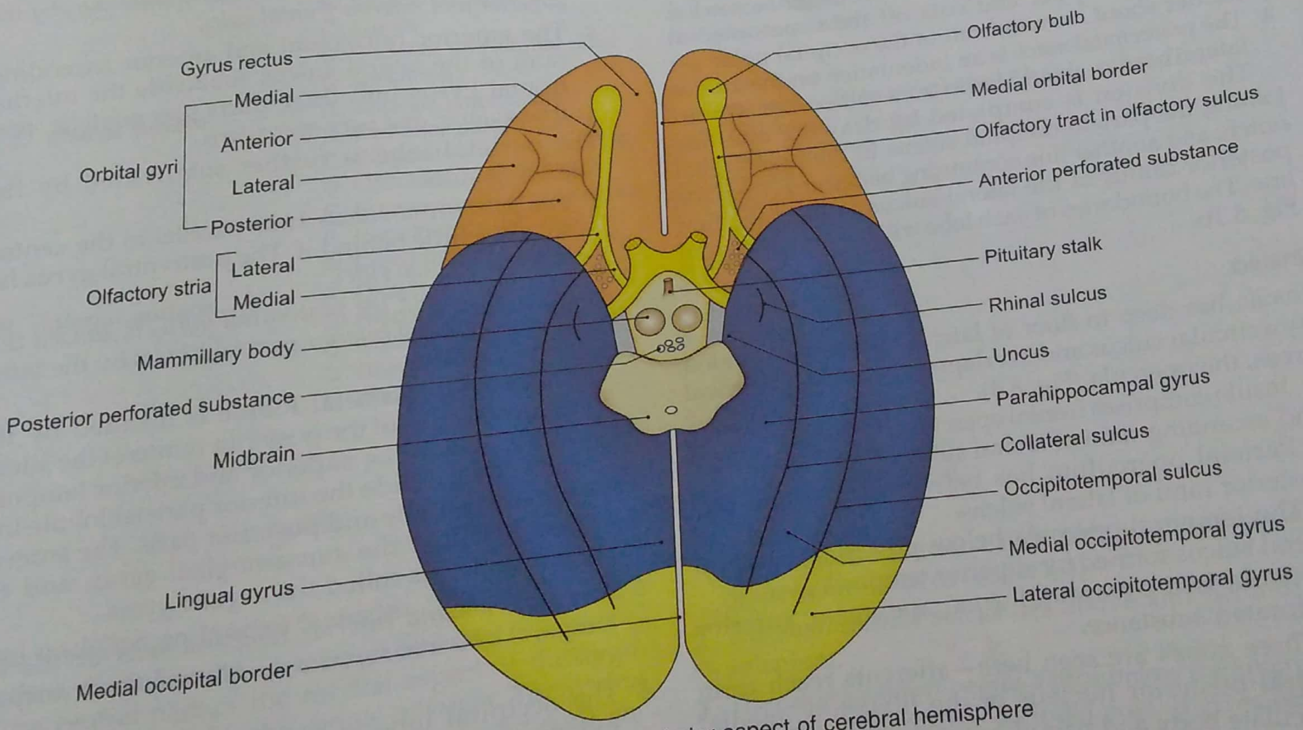


Fig. 8.5: Gyri and sulci on the inferior aspect of cerebral hemisphere

5 cm in front of the occipital pole, it is called the preoccipital notch (Fig. 8.1).

3 *Medial orbital border* separates the medial surface from the orbital surface (Fig. 8.4).

4 *Medial occipital border* separates the medial surface from the tentorial surface (Fig. 8.4).

Three Poles

1 *Frontal pole*, at the anterior end.

2 *Occipital pole*, at the posterior end.

3 *Temporal pole*, at the anterior end of the temporal lobe (Fig. 8.1).

Lobes of Cerebral Hemisphere

Each cerebral hemisphere is divided into four lobes—frontal, parietal, occipital and temporal. Their positions correspond, very roughly, to that of the corresponding bones. The lobes are best appreciated on the superolateral surface (Fig. 8.2). The sulci separating the lobes on this surface are as follows:

1 The *central sulcus* begins at the superomedial border of the hemisphere a little behind the midpoint between the frontal and occipital poles. It runs on the superolateral surface obliquely downwards and forwards and ends a little above the posterior ramus of the lateral sulcus (Fig. 8.2).

2 It is seen that the *lateral sulcus* separates the orbital and tentorial parts of the inferior surface. Laterally, this sulcus reaches the superolateral surface where it divides into anterior, ascending and posterior branches. The largest of these, the *posterior ramus of the lateral sulcus* passes backwards and slightly upwards over the superolateral surface.

3 The *parieto-occipital* sulcus is a sulcus of the medial surface. Its upper end cuts off the superomedial border about 5 cm in front of the occipital pole.

4 The *preoccipital notch* is an indentation on the inferolateral border, about 5 cm in front of the occipital pole.

The division is completed by drawing one line joining the parieto-occipital sulcus to the preoccipital notch; and another line continuing backwards from the posterior ramus of the lateral sulcus to meet the first line. The boundaries of each lobe will now be clear from Fig. 8.1b.

Insula

Insula lies deep in floor of lateral fissure surrounded by a circular sulcus and overlapped by adjacent cortical areas, the opercula (Fig. 8.3).

Insula comprises frontal operculum between anterior and ascending rami of lateral sulcus.

Parietal operculum lies between ascending and posterior rami of lateral sulcus.

The temporal opercula below posterior ramus of lateral sulcus formed by superior temporal gyri.

Insula is a pyramidal area, apex near anterior perforated substance.

Three zones are seen here—afferents reach from ventral posterior nucleus of the thalamus, medial geniculate body and part of pulvinar.

Efferents reach from areas 5, 7, olfactory, limbic system and amygdala.

Role of anterior insular cortex is in olfaction and taste.

Role of posterior insular cortex is in language function.

Sulci and Gyri on Superolateral Surface

These are shown in Fig. 8.2 and Table 8.1.

1 The *central sulcus* (Latin *furrow*) has been described earlier. The upper end of the sulcus extends for a short distance on to the medial surface (where it will be examined later).

2 We have seen that the *lateral sulcus* begins on the inferior surface. On reaching the lateral surface, it divides into three rami. The largest of these is the *posterior ramus*. The posterior end of this ramus turns upwards into the temporal lobe. The other rami of the lateral sulcus are the *anterior horizontal and anterior ascending rami*. They extend into the lower part of the frontal lobe.

3 The frontal lobe is further divided by the following sulci.

   a. The *precentral sulcus* runs parallel to the central sulcus, a little in front of it. The *precentral gyrus* lies between the two sulci (Table 8.1).

   b. The area in front of the precentral sulcus is divided into *superior, middle and inferior frontal gyri by the superior and inferior frontal sulci.*

   c. The anterior horizontal and anterior ascending rami of the lateral sulcus subdivide the inferior frontal gyrus into three parts *pars orbitalis, pars triangularis, and pars opercularis.*

4 The parietal lobe is further subdivided by the following sulci:

   a. The *postcentral sulcus* runs parallel to the central sulcus, a little behind it. The postcentral gyrus *lies between the two sulci.*

   b. *The area behind the postcentral gyrus is divided into the superior and inferior parietal lobules* by the *intraparietal sulcus.*

   c. The inferior parietal lobule is invaded by the upturned ends of the posterior ramus of the lateral sulcus, and of the superior and inferior temporal sulci. They divide the inferior parietal lobule into anterior, middle and posterior parts. The anterior part is called the *supramarginal gyrus*, and the middle part is called the *angular gyrus.*

5 The *superior and inferior temporal sulci* divide the temporal lobe into *superior, middle and inferior temporal gyri.*

6 The occipital lobe is further subdivided by the following sulci.

   a. The *lateral occipital sulcus* divides this lobe into the *superior and inferior occipital gyri.*

   b. The *lunate sulcus* separates these gyri from the occipital pole.

   c. The area around the parieto-occipital sulcus is the *arcus parieto-occipitalis.* It is separated from the superior occipital gyrus by the *transverse occipital sulcus.*

Table 8.1: Sulci and gyri of the cerebrum

Surface/Lobe	Sulci	Gyri
I. Superolateral surface		
1. Frontal lobe	A. Precentral B. Superior frontal C. Inferior frontal	a. Precentral b. Superior frontal c. Middle frontal d. Inferior frontal which also contains anterior horizontal and anterior ascending rami of the lateral sulcus, and the pars orbitalis, pars triangularis and pars opercularis
2. Parietal lobe	A. Postcentral B. Intraparietal	a. Postcentral b. Superior parietal lobule c. Inferior parietal lobule, which is divided into 3 parts: i. The anterior, supramarginal ii. The middle, angular iii. The posterior, over the upturned end of inferior temporal sulcus
3. Temporal lobe	A. Superior temporal B. Inferior temporal	a. Superior temporal b. Middle temporal c. Inferior temporal
4. Occipital lobe	A. Transverse occipital B. Lateral occipital C. Lunate D. Superior and inferior polar E. Calcarine	a. Arcus parieto-occipitalis b. Superior occipital c. Inferior occipital d. Gyrus descendens
II. Medial surface	A. Anterior parolfactory B. Posterior parolfactory C. Cingulate D. Callosal E. Suprasplenial or subparietal F. Parieto-occipital G. Calcarine	a. Paraterminal b. Paraolfactory (subcallosal area) c. Medial frontal d. Paracentral lobule e. Cingulate f. Cuneus g. Precuneus
III. Inferior surface	A. Olfactory B. H-shaped orbital sulci C. Collateral D. Rhinal E. Occipitotemporal	a. Gyrus rectus b. Anterior orbital c. Posterior orbital d. Medial orbital e. Lateral orbital f. Lingual g. Uncus h. Parahippocampal i. Medial occipitotemporal j. Lateral occipitotemporal

Sulci and Gyri on Medial Surface

Confirm the following facts by examining (Fig. 8.3).

The central part of the medial aspect of the hemisphere is occupied by the *corpus callosum*. The corpus callosum is divisible into the *genu* (anterior end), the *body*, and the *splenium* (posterior end). It is made up of nerve fibres connecting the two cerebral hemispheres. Below the corpus callosum, there are the *septum pellucidum*, the *fornix* and the *thalamus*. In the remaining part of the medial surface, identify the following sulci.

1 The *cingulate sulcus* starts in front of the genu and runs backwards parallel to the upper margin of the corpus callosum. Its posterior end reaches the superomedial border a little behind the upper end of the central sulcus (Table 8.1).

2 The *suprasplenial sulcus* lies above and behind the splenium.

3 The *calcarine sulcus* begins a little below the splenium and runs towards the occipital pole. It gives off the *parieto-occipital sulcus* which reaches the superolateral surface.

4 A little below the genu, there are two small anterior and posterior *paraolfactory sulci*.

The following gyri can now be identified.

1 The *cingulate gyrus* lies between the corpus callosum and the cingulate sulcus. Its posterior part is bounded

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above by the *suprasplenial sulcus* and is divided into anterior and posterior parts.

2 The U-shaped gyrus around the end of the central sulcus is the *paracentral lobule*. It is usually divided into anterior and posterior parts.

3 The area between the cingulate gyrus and the superomedial border in front of the paracentral lobule is called the *medial frontal gyrus*.

4 The quadrangular area between the suprasplenial sulcus and the superomedial border is called the *precuneus*.

5 The triangular area between the parieto-occipital sulcus (above) and the calcarine sulcus (below) is called the *cuneus*.

6 A narrow strip between the splenium and the stem of the calcarine sulcus is the *isthmus*.

7 The *paraterminal gyrus* lies just in front of the lamina terminalis.

8 The *paraolfactory gyrus* lies between the anterior and posterior parolfactory sulci.

Sulci and Gyri on the Orbital Surface

1 Parallel to the medial orbital border there is the *olfactory sulcus;* between these two there is the *gyrus rectus*. The rest of the orbital surface is subdivided by an H-shaped sulcus into *anterior, posterior, medial and lateral orbital gyri*.

2 The stem of the lateral sulcus lies deep between the temporal pole and orbital surface (Fig. 8.4).

Sulci and Gyri on the Tentorial Surface

This area presents two sulci running anteroposteriorly. The medial one is the *collateral sulcus*, and the lateral is the *occipitotemporal sulcus*. On the medial side of the temporal pole, there is the *rhinal sulcus*.

The gyri are as follows:

1 The part medial to the rhinal sulcus is the *uncus*.

2 The part medial to the collateral sulcus is the *parahippocampal gyrus*. Its posterior part is limited medially by the calcarine sulcus. It is joined to the cingulate gyrus through the isthmus (Fig. 8.3).

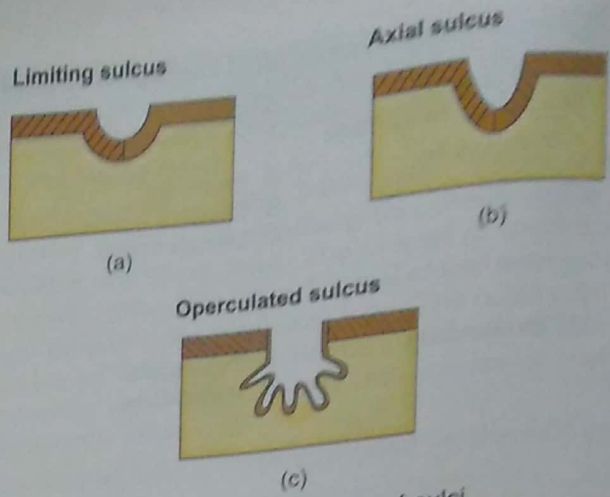
3 The part lateral to the collateral sulcus is divided into *medial and lateral occipitotemporal gyri* by the *occipitotemporal sulcus*.

Types of Sulci

According to Function

1 Limiting sulcus separates at its floor two areas which are different functionally and structurally.
For example, the central sulcus between the motor and sensory areas (Fig. 8.6a).

2 Axial sulcus develops in the long axis of a rapidly growing homogeneous area.



Figs 8.6a to c: Types of sulci

For example, the postcalcarine sulcus in the long axis of the striate area (Fig. 8.6b).

3 Operculated sulcus separated by its lips in two areas, and contains a third area in the walls of the sulcus. For example, the lunate sulcus (Fig. 8.6c).

According to Formation

1 Primary sulci formed before birth, independently. Example is central sulcus.

2 Secondary sulcus is produced by factors other than the exuberant growth in the adjoining areas of the cortex. Examples are the lateral and parieto-occipital sulci.

According to Depth

1 Complete sulcus is very deep so as to cause elevation in the walls of the lateral ventricle. Examples are the collateral and calcarine sulci.

2 Incomplete sulci are superficially situated and are not very deep, e.g. precentral sulcus.

Structural and Functional Types of the Cortex

1 *Allocortex (archipallium):* It is the original olfactory cortex, and is represented by rhinencephalon (piriform area and hippocampal formation). Structurally, it is simple and is made up of only three layers.

2 *Isocortex (neopallium):* It is the lately acquired cortex, containing various centres other than those for smell. Structurally, it is thick and six layered. It is subdivided into the following.
   a. Granular cortex (koniocortex or dust cortex). It is basically a sensory cortex.
   b. Agranular cortex. This is the motor cortex.

FUNCTIONAL OR CORTICAL AREAS OF CEREBRAL CORTEX

Functionally, the cortex is divided into number of areas by many neurobiologists. Brodmann's areas are taken normally according to whom there are 200 areas. There are three basic functional divisions of cerebral cortex:

1 *Motor areas:* The primary motor area has been identified on the basis of elicitation of motor responses at a low threshold of electric stimulation which gives rise to contraction of skeletal musculature. These areas give origin to corticospinal and corticonuclear fibres (Figs 8.7 and 8.8).

2 *Sensory areas:* In these areas, electrical activity can be recorded if appropriate sensory stimulus is applied to a particular part of the body (Fig. 8.8).

The ventral posterior nucleus of thalamus is main source of afferent fibres for the first sensory area. This thalamic nucleus is the site of termination of all the fibres of the medial lemniscus and of most of the spinothalamic and trigeminothalamic tracts.

3 *Association areas:* In these regions, the direct sensory or motor responses are not elicited. These areas integrate and analyse the responses from various sources. Many such areas are known to have motor or sensory functions.

The motor and sensory functions also overlap in the same region of cortex. If the motor function is predominant, it is known as motor-sensory (Ms) and where sensory function is predominant, it is called sensorimotor (Sm).

Motor Areas

Primary Motor Area

It is located in the precentral gyrus, including the anterior wall of central sulcus, and in the anterior part

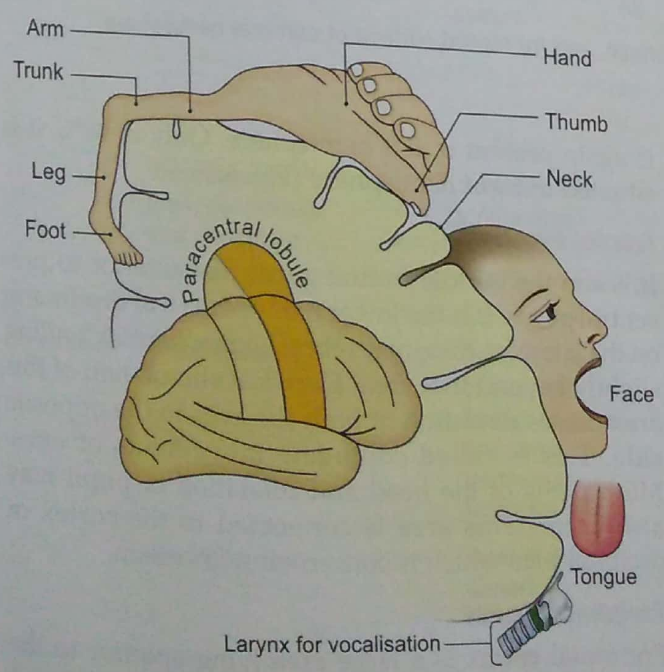


Fig. 8.7: Motor homunculus on the precentral gyrus

of paracentral lobule on the medial surface of cerebral hemispheres. This corresponds to area 4 of Brodmann.

Electrical stimulation of primary motor area elicits contraction of muscles that are mainly on the opposite side of body. Although cortical control of musculature is mainly contralateral, there is significant ipsilateral control of most of the muscles of the head and axial muscles of the body. The contralateral half of the body is represented as upside down, except the face. The pharyngeal region, tongue are represented in the most ventral and lower part of precentral gyrus, followed by the face, hand, arm, trunk and thigh. The remainder of leg, foot and perineum is on the medial surface of hemisphere in the paracentral lobule (Fig. 8.7).

Another significant feature in this area is that the size of the cortical area for a particular part of the body is determined by the functional importance of the part and its need for sensitivity and intricacy of the movements of that region. The area for the face, especially the *larynx and lips*, is therefore disproportionately large and a large area is assigned to the hand particularly the thumb and index finger. Movements of joints are represented rather than individual muscles (Table 8.2).

Connections of motor area:

Afferents:

- From the ventral nucleus of thalamus and contralateral cerebellar hemispheres
- From the opposite hemispheric cortical areas.

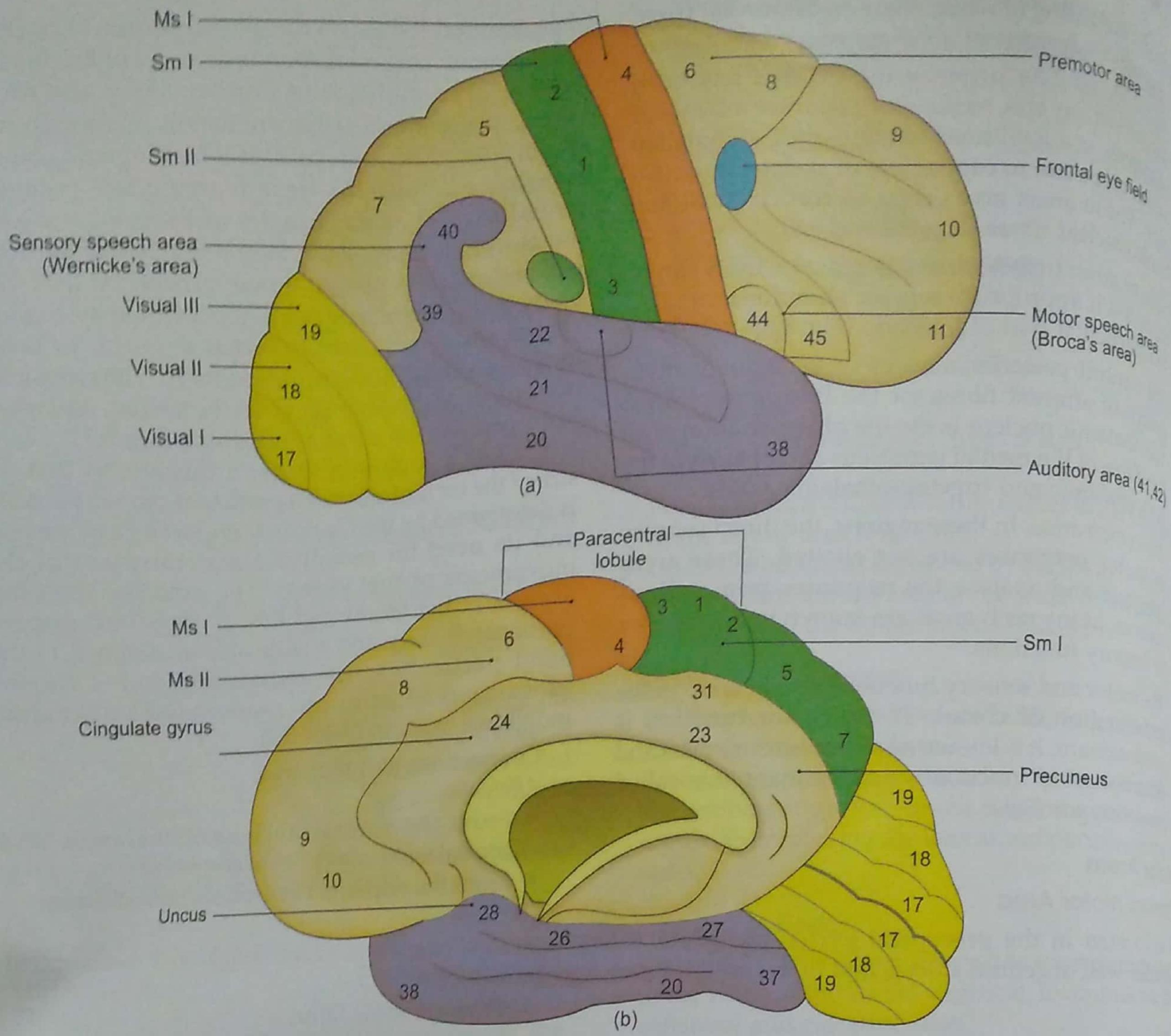
Efferents:

- Corticonuclear, corticobulbar and corticospinal tracts
- Frontopontine fibres
- Projection fibres to basal ganglia

Premotor Area

This area coincides with the Brodmann's area 6 and is situated anterior to motor area in the superolateral and medial surfaces of the hemisphere. The premotor area contributes to motor function by its direct contribution to the pyramidal and other descending motor pathways and by its influence on the primary motor cortex (Fig. 8.8).

In general, the primary motor area is the cortex in which execution of movements originates and relatively simple movements are maintained. In contrast, the premotor area programmes skilled motor activity and thus directs the primary motor area in its execution. The premotor and primary motor areas are together referred to as the primary somatomotor area (Ms I). Both these areas give origin to corticospinal and corticonuclear fibres and receive fibres from cerebellum after relay in ventral intermediate nucleus of thalamus. It has same connections as motor area.



Figs 8.8a and b: Functional areas: (a) Superolateral surface, and (b) medial surface of cerebral hemisphere

Supplementary Motor Area (Ms II)

It is predominantly motor in function. This motor area is in the part of area 6 that lies on the medial surface of the hemisphere anterior to the paracentral lobule. Different parts of body are represented within this area. It differs from the main motor area in that its stimulation produces bilateral movements (Fig. 8.8). Its function is to control complex movements which require sequential organisation.

Motor Speech Area of Broca
(French Neurologist 1824–80)

This area occupies the opercular and triangular portions of the inferior frontal gyrus corresponding to the areas 44 and 45 of Brodmann. This is present on the left side in 98% of right-handed persons. In 70% of left handers, it is again present in left hemisphere. Only in 30%, it is situated in right hemisphere (Fig. 8.8).

Frontal Eye Field

It lies in the middle frontal gyrus just anterior to precentral gyrus. It is the lower part of area 8 of Brodmann on the lateral surface of cerebral hemisphere, extending slightly beyond that area. Electrical stimulation of this area causes deviation of both the eyes to the opposite side. This is called conjugate movements of eyes. Movements of the head and dilatation of pupil may also occur. This area is connected to the cortex of occipital lobe which is concerned with vision.

Prefrontal Cortex

Prefrontal cortex is a large area lying anterior to the precentral area. It includes the superior, middle, and

Table 8.2: Functional areas of the cerebral cortex

Lobe	Area	Area no.	Location	Representation of body parts	Function	Effect of lesion
Frontal	Motor	4	Precentral gyrus and paracentral lobule	Upside down except face	Controls voluntary activities of the opposite half of body	Contralateral paralysis and Jacksonian fits
	Premotor	6	Posterior parts of superior, middle and inferior frontal gyri	—	Controls extrapyramidal system	Often mixed with pyramidal effect
	Frontal eye field	6, 8	Posterior part of middle frontal gyrus	—	Controls horizontal conjugate movements of the eyes	Horizontal conjugate movements are lost
	Motor speech (Broca's area)	44, 45	Pars triangularis and pars opercularis	—	Controls the spoken speech	Aphasia (motor)
	Prefrontal	9,10,11 12	The remaining large, anterior part of frontal lobe	—	Controls emotions, concentration, attention initiative and judgement	Loss of orientation
Parietal	Sensory (somesthetic)	3, 1, 2	Postcentral gyrus and paracentral lobule	Upside down except face	Perception of exteroceptive (touch, pain and temperature) and proprioceptive impulses	Loss of appreciation of the impulses received
	Sensory association	5,7	Between sensory and visual areas	—	Stereognosis and sensory speech	Astereognosis and sensory aphasia
	(Wernicke's area)	40	Inferior part of parietal lobule	—	Sensory speech	Sensory aphasia
Occipital	Visuosensory area or striate	17	In and around the postcalcarine sulcus	Macular area has largest representation	Reception and perception of the isolated visual impressions of colour, size, form, motion, illumination and transparency	Homonymous hemianopia with macular sparing
	Visuopsychic area, parastriate and peristriate	18, 19	Surround the striate area	—	Correlation of visual impulses with past memory and recognition of objects seen, and also the depth	Visual agnosia
Temporal	Auditosensory	41, 42	Posterior part of superior temporal gyrus and anterior transverse temporal gyrus	—	Reception and perception of isolated auditory impressions of loudness, quality and pitch	Impaired hearing
	Auditopsychic	22	Rest of the superior temporal gyrus	—	Correlation of auditory impressions with past memory and identification (interpretation) of the sounds heard	Auditory agnosia

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inferior frontal gyri, medial frontal gyrus, orbital gyri and anterior half of the cingulate gyrus. These include Brodmann's areas 9, 10, 11 and 12. This area is connected to other areas of the cerebral cortex, corpus striatum, thalamus and hypothalamus. It is also connected to cerebellum through the pontine nuclei. It controls emotions concentration, attention, initiative and judgement. It has reciprocal connections with thalamic dorsomedial nucleus, hypothalamus, and limbic system.

CLINICAL ANATOMY

Motor areas

- Destructive lesion of primary motor area 4 results in voluntary paresis of the affected part of body. Spastic voluntary paralysis of the opposite side of body characteristically follows if the lesion spreads beyond area 4 or that interrupts projection fibres in the medullary centre or internal capsule. Irritative lesion of the motor area leads to focal convulsive movements of the corresponding part of body, referred to as *Jacksonian epilepsy*.
- Lesion of supplementary motor area 6 leads to apraxia and akinesia. This is the condition which involves difficulty in performing the skilled movements once learnt, in absence of paralysis, ataxia or sensory loss. When the disability affects writing, it is called *agraphia*.
- Frontal eye field: Destruction of this area causes conjugate deviation of the eyes towards the side of lesion. The patient cannot voluntarily move his eyes in the opposite direction, but this movement occurs involuntarily when he observes an object moving across the field of vision.
- Speech area: Lesion of Broca' s area on the dominant side of hemisphere causes expressive aphasia. It is characterised by hesitant and distorted speech with relatively good comprehension.
- A lesion involving language areas *(Wernicke's area* and *Broca's area)* leads to receptive aphasia. In this condition, auditory and visual comprehension of language that is naming of objects and repetition of a sentence spoken by the examiner are all defective (Fig. 8.8a).
- A lesion involving Wernicke's area and superior longitudinal fasciculus or arcuate fasciculus results in *jargon aphasia* in which speech is fluent but unintelligible jargon.
- Voluntary smile in a stroke patient will accentuate the asymmetry. A genuine smile which uses only extrapyramidal pathways, will be symmetrical and there will be no asymmetry for the duration of the smile. One needs to remember that motor cortex is required only for voluntary moment.

Sensory Areas

First Somesthetic Area

First somesthetic (general sensory) area is also called *first somatosensory area* (Sm I). It occupies postcentral gyrus on the superolateral surface of the cerebral hemisphere and posterior part of paracentral lobule on the medial surface. It corresponds to areas 3, 1 and 2 of Brodmann (Figs 8.8 and 8.9).

The representation of the body in this area corresponds to that in the motor area that is contralateral half of body is represented upside down except the face. The area of the cortex that receives sensations from a particular part of body is not proportional to the size of that part, but rather to the intricacy of sensations received from it. Thus, the thumb, fingers, lips and tongue have a disproportionately large representation. The different sensations, i.e. cutaneous and proprioceptive are represented in different parts within sensory area.

The ventral posterior nucleus of thalamus is the main source of afferent fibres for the sensory area. This thalamic nucleus is the site of termination of all the fibres of the medial lemniscus. Most of the fibres of the spinothalamic and trigeminothalamic tracts carrying fibres for cutaneous sensibility end in anterior part of the area and those for deep sensibility end in the posterior part.

Second Somesthetic Area

Second somesthetic area also known as second *somatosensory area* (Sm II) has been demonstrated in primates including humans. This is situated in the superior lip of the posterior ramus of lateral sulcus with postcentral gyrus. The parts of body are represented bilaterally (Fig. 8.8).

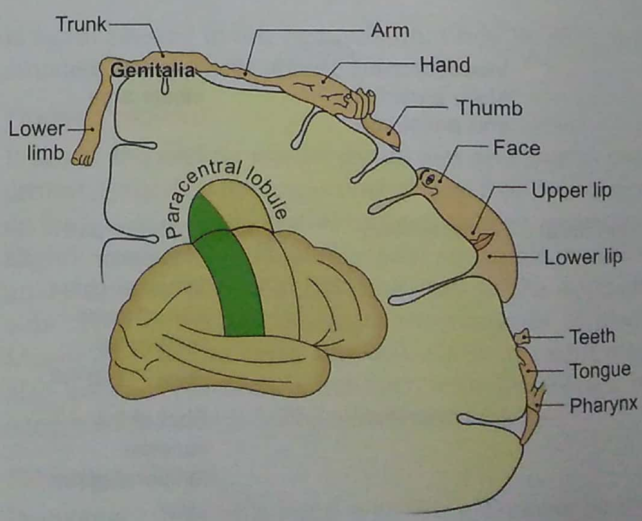


Fig. 8.9: Sensory homonculus of the postcentral gyrus

Somesthetic Association Cortex

Somesthetic association cortex is mainly in the superior parietal lobule on the superolateral surface of the hemisphere and in the precuneus on the medial surface. It coincides with areas 5 and 7 of Brodmann. This receives afferents from first sensory area and has reciprocal connection with dorsal tier of nuclei of lateral mass of thalamus. Data pertaining to the general senses are integrated, permitting a comprehensive assessment of the characteristic of an object held in hand and its identification without visual aid.

Receptive Speech Area of Wernicke

(German Neurologist 1848–1903)

This is also known as *sensory language area*. It consists of auditory association cortex and of adjacent parts of the inferior parietal lobule (Fig. 8.8).

CLINICAL ANATOMY

Sensory areas

- First somesthetic or general sensory area (areas 3, 1 and 2 of Brodmann). When this part of cortex is the site of destructive lesion, a crude form of awareness persists for the sensation of pain, heat and cold on the opposite side of lesion. There is poor localization of stimulus. There is loss of discriminative sensations of fine touch, movements and position of part of the body.
- Somesthetic association cortex (superior parietal lobule) areas 5 and 7 of Brodmann: A lesion in this area leads to defect in understanding the significance of sensory information, which is called *agnosia*. A lesion that destroys a large portion of this association cortex causes tactile agnosia and *astereognosis* which are closely related. This is the condition when a person is unable to recognize the objects held in the hand, while the eyes are closed. He is unable to correlate the surface, texture, shape, size and weight of the object or to compare the sensations with previous experience.

Areas of Special Sensations

Vision

The *visual area* is located above and below the calcarine sulcus on the medial surface of occipital lobe. It corresponds to area 17 of Brodmann. The visual area is also called the striate area because the cortex here contains the *line of Gennari*, which is just visible to the unaided eye.

The chief source of afferent fibres to area 17 is the *lateral geniculate nucleus* of thalamus by way of geniculocalcarine tract. Area 17 constitutes the first visual area. It is continuous both above and below with area 18 and beyond this with area 19 of Brodmann which are also known as visual association or psychovisual areas. Since fibres of geniculocalcarine tract (optic radiation) terminate in these regions also, therefore, these areas are regarded as second and the third visual areas respectively (Fig. 8.8).

The role of the second and third visual areas includes among other complex aspects of vision, the relating of present to past visual experience, with recognition of what is seen and appreciation of its significance. The three areas are linked together by association fibres. The visual areas give efferent fibres which reach frontal eye field.

Hearing

The *auditory* (acoustic) *area* lies in the temporal lobe. Most of it is concealed as it lies in that part of superior temporal gyrus which forms inferior wall of the posterior ramus of lateral sulcus. It corresponds with areas 41 and 42 of Brodmann.

The *medial geniculate* body of the thalamus is the principal source of fibres ending in the auditory cortex with these fibres constituting the auditory radiation. There is spatial representation in the auditory area with respect to pitch of sounds. Impulses of low frequencies impinge on anterolateral part of area and impulses of high frequencies get heard on the posteromedial part.

Cortex gets afferents from both ears. Body receives information that originates mainly in the organ of Corti of opposite side, the incomplete decussation of ascending pathways ensures a substantial input from the ear of same side as well (Fig. 8.8).

The auditory radiation does not only end in first auditory area but extends to neighbouring area as well, that is known as auditory association area or second auditory area. This area lies behind the first auditory area in superior temporal gyrus. It corresponds to area 22 of Brodmann on the lateral surface of superior temporal gyrus. This region of the cortex is also known as *Wernicke's area* and is of major importance in language functions.

Taste

The taste area (gustatory area) is located in dorsal wall of posterior ramus of lateral sulcus, with extension into insula and corresponds to *area 43 of Brodmann*. It places the taste area adjacent to first sensory area of cortex for tongue and pharynx. Its location is similar to second somesthetic area.

Smell

Ends in pyriform lobe.

CLINICAL ANATOMY

Special sensory areas

a. Primary visual area 17: Lesion of this area, leads to loss of vision in the visual field of the opposite side—homonymous hemianopia.

b. Auditory area:
   - Primary auditory areas 41 and 42: A unilateral lesion involving the auditory area causes diminution in the acuity of hearing in both ears and the loss is greater in the opposite ear. However, the impairment is slight because of the bilateral projection to the cortex and the deficit is difficult to detect by clinical tests.
   - Auditory association cortex or secondary area 22. In lesions of this area, interpretation of the sounds is lost.

Functions of Cerebral Cortex

1 *Cerebral dominance:* One cerebral hemisphere dominates the ot er one in relation to handedness, speech, perception of language and spatial judgement. In 80–95% subjects, the left hemisphere dominates the right one. The dominant lobe contains the Broca's motor speech area. Since left hemisphere controls the right half of the body, all these subjects are right-handed. The left hemisphere is verbal, mathematical, analytical, scientific, calculative and has direct link to consciousness.

The right hemisphere is active in understanding geometrical figures imaginative, artistic, religious, and important for temporal synthesis and spatial comprehension. It helps in recognition of faces, figures and appreciating music.

Localisation of speech on left side in 70% of left handed and 98% of right handed is well known. Association of negative emotions with right prefrontal activity and of positive emotions with left prefrontal activity is also known. Mahatma Gandhi, father of the nation, Bill Clinton, Bill Gates, Amitabh Bachchan and Abhishek Bachchan, are all left handed. Functional asymmetry in a structurally symmetrical structure is a great and ingenious way of economising on neural tissue. It practically doubles the capabilities of the brain. Women mostly operate through right hemisphere while men mostly use their dominant left hemisphere.

2 *Discriminatory aspects:* Sensory cortex is not concerned with recognition only, but is also involved with discrimination of sensory function as:

a. Recognition of spatial relationship

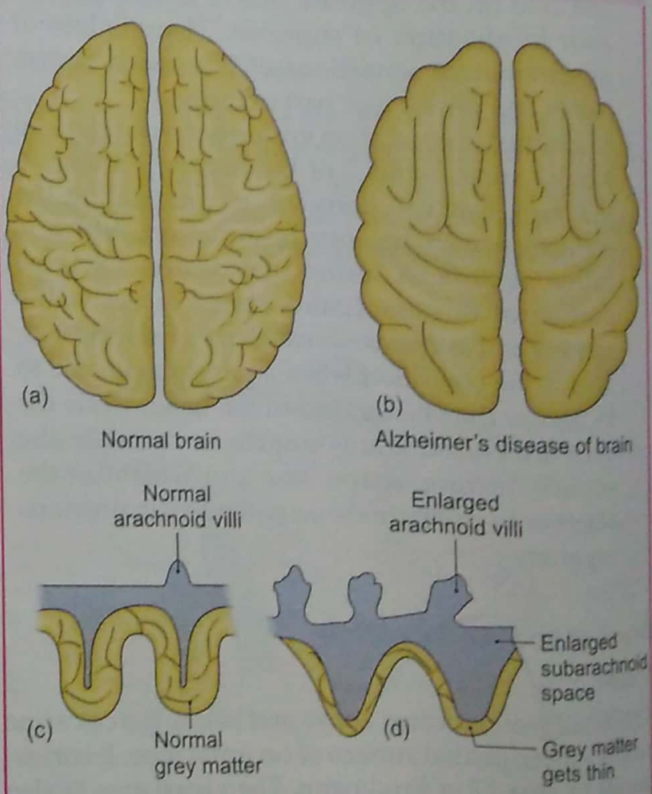
b. Graded response to stimuli of different intensities

c. Appreciation of similarities and differences in external objects, brought into contact with surface of body.

3 *Associative functions:* The information thus discriminated and classified is correlated with previous experience. This association forms the basis of memory patterns. These are transmitted to frontal cortex which synthesize it and forms basis of thinking and related intellectual activities.

CLINICAL ANATOMY

- Table 8.3 depicts summary of functions and effects of damage of lobes of brain. Figures 8.10a and c show normal brain.
- *Ageing:* Usually after 60–70 years or so there are changes in the brain. These are:
  a. Prominence of sulci due to cortical shrinkage (Fig. 8.10b).
  b. The gyri get narrow and sulci get broad (Fig. 8.10d).
  c. The subarachnoid space becomes wider.
  d. There is enlargement of the ventricles.
- *Dementia:* In this condition, there is slow and progressive loss of memory, intellect and personality. The consciousness of the subject is normal. Dementia usually occurs due to Alzheimer's disease.
- *Alzheimer's disease:* The changes of normal ageing are more pronounced in the parietal lobe, temporal lobe, and in the hippocampus.



Figs 8.10a to d: (a) Normal brain, (b) Alzheimer's disease of brain, (c) normal grey matter and arachnoid villi, and (d) changes in the elderly brain

Table 8.3: Summary of functions and effects of damage of lobes of brain (Fig. 8.1)

Lobes of brain	*Functions*	*Effects of damage*
Frontal	Personality, emotional control, social behaviour, contralateral motor control, language and micturition	Lack of initiation, antisocial behaviour, impaired memory and incontinence
Parietal (non-dominant)	Spatial orientation, recognition of faces, appreciation of music and figures	Spatial disorientation, non-recognition of faces
Parietal (dominant)	Language, calculation, analytical, logical, and geometrical	Dyscalculia, dyslexia, apraxia (inability to do complex movements) and agnosia (inability to recognize)
Temporal (non-dominant)	Auditory perception, pitch perception, non-verbal memory, smell and balance	Reception aphasia and impaired musical skills
Temporal (dominant)	Language, verbal memory and auditory perception	Dyslexia, verbal memory impaired and receptive aphasia
Occipital	Visual processing	Visual loss and visual agnosia

HUMAN SPEECH

There have been many evolutionary changes in human for the purpose of articulation. These are

i. Bipedal position
ii. Flexed skull
iii. Increased growth of prefrontal part of brain
iv. Receding of the lower jaw
v. Decreased distance between posterior border of hard palate and anterior margin of foramen magnum
vi. Larynx pulled downwards
vii. Posterior one-third of tongue pulled downwards and facing backwards forming the anterior wall of the laryngopharynx
viii. Cavity of mouth and of pharynx being at right angle to each other
ix. Anterior two-thirds of tongue being thin and more agile, voice produced due to tongue touching the palate was clear and sharp.

Before the origin of language was the evolution of music. Music is in biology of all living beings; it generates different emotions and is universal. Music was the only way to communicate with or attract the female. Language generates much less or no emotions and is not universal.

Broca's area on left side is related to speech; on the right side is related to music, poetic expressions, figures, faces, etc. Broca's area: Neural circuits are formed for articulation of different phenomes.

The temporal lobe contains auditory area which receives the sound waves. Above and behind auditory area is Wernicke's area. This area is responsible for comprehension of stimuli received by auditory area. It is seven times larger in human than in a chimpanzee.

Wernicke's area organizes the matter to be uttered by articulatory system. This area also makes complex sentences. A bundle of fibres, arcuate fibers connect Wernicke's and Broca's areas. This bundle carries the organized and composed speech of Wernicke's area to the Broca's area for speaking.

Temporal lobe on its inner aspect contains hippocampus and globular amygdala on its anterior aspect. Hippocampus area stores long-term memories. Amygdala is concerned with primary emotions. It receives as well as initiates emotions and recognizes faces. Limbic system comprises hippocampus, amygdala, cingulate gyrus and basal nuclei.

Frontal lobe's functions are intelligence and cognitive ability.

In modern human, inferior parietal lobule area is considerably enlarged. The gyri are supramarginal and angular gyri.

Supramarginal gyrus is used for fine finger movement, tongue movement, fine facial movement. In this area, visual perception, perception of auditory sense, and knowledge of position of joints come together. Inferior parietal lobule is important for speech.

Phenome is the smallest unit of speech.

Word is the smallest unit of language. Words are composed of phenomes.

Prosodic functions (high and low of voice) are related to thalamus and basal ganglia. Prosodic aspect of speech is less in parkinsonism wherein the speech gets monotonous without any prosodic effects as there is lack of dopamine.

Source: Lele, DN: The Evolutions of Speech and Language, CBS Publishers & Distributors, New Delhi, 2016. (Dr DN Lele, Director, Lele Hospital and Research Centre, Nashik, Maharashtra, is an otolaryngologist of international repute).

Brain–Neuroanatomy

DIENCEPHALON

The diencephalon is a middle structure which is largely embedded in the cerebrum, and therefore hidden from surface view (Figs 8.11a and b). Its cavity forms the greater part of the third ventricle. The hypothalamic sulcus, extending from the interventricular foramen to the cerebral aqueduct, divides each half of the diencephalon into dorsal and ventral parts. Further subdivisions are given below.

DORSAL PART OF DIENCEPHALON

1 Thalamus (dorsal thalamus).
2 Metathalamus, including the medial and lateral geniculate bodies, described with thalamus.
3 Epithalamus, including the pineal body and habenula.

VENTRAL PART OF DIENCEPHALON

1 Hypothalamus, and
2 Subthalamus (ventral thalamus).

Thalamus

The thalamus (Greek *inner chamber*) is a large mass of grey matter 4 cm each in transverse, vertical and anteroposterior diameters situated in the lateral wall of the third ventricle and in the floor of the central part of the lateral ventricle.

Measurements:

Anteroposterior—4 cm
Vertical—4 cm
Transverse—4 cm

It has anterior and posterior ends; superior, inferior, medial and lateral surfaces.

The *anterior end* with anterior nucleus is narrow and forms the posterior boundary of the interventricular foramen (Figs 8.11a and b).

The *posterior end* is expanded, and is known as the pulvinar. It overhangs the lateral and medial geniculate bodies, and the superior colliculus with its brachium (Fig. 8.11a).

The *superior surface* is divided into a lateral ventricular part which forms the floor of the central part of the lateral ventricle, and a medial extraventricular part which is covered by the tela choroidea of the third ventricle by the free margin of body of fornix. It is limited laterally by the caudate nucleus, the stria terminalis and the thalamostriate vein, and medially by the habenular stria (stria medullaris thalami) (Fig. 8.17).

The *inferior surface* rests on the subthalamus and the hypothalamus (Fig. 8.18).

The *medial surface* forms the posterosuperior part of the lateral wall of the third ventricle (*see* Fig. 9.3). The medial surfaces of two thalami are interconnected by an interthalamic adhesion (Fig. 8.12).

The *lateral surface* forms the medial boundary of the posterior limb of the internal capsule (Fig. 8.20).

Structure and Nuclei of Thalamus

White matter

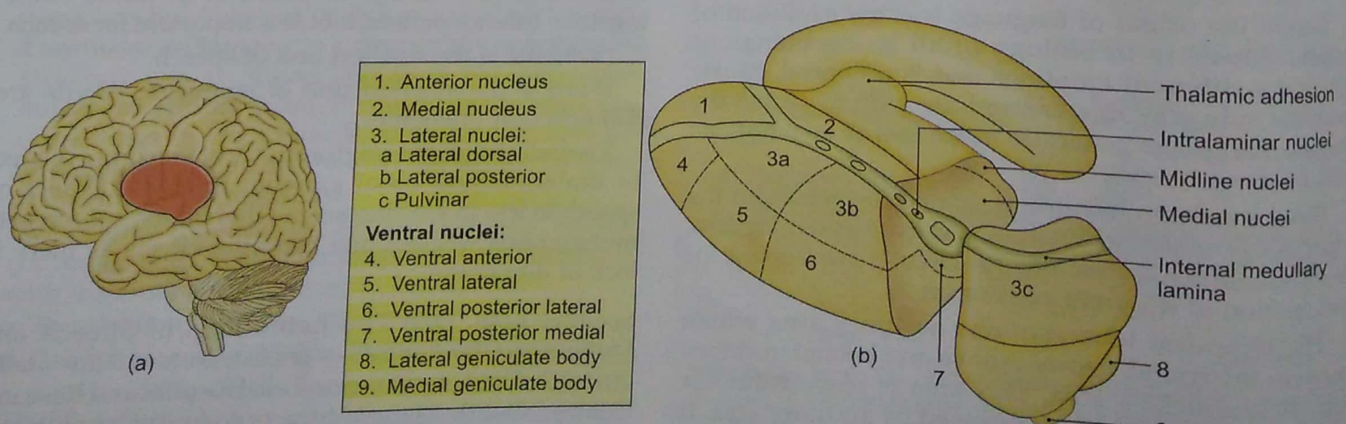
The *external medullary lamina* covers the lateral surface.

The *internal medullary lamina* divides the thalamus into three parts—anterior, medial and lateral.

Grey matter

The grey matter is divided to form several nuclei.

1 *Anterior nucleus* in the anterior part (Fig. 8.13).
2 *Medial nucleus* in the medial part.
3 The lateral part of the thalamus is largest and represents the *neothalamus*. It is divided into the *lateral nucleus* in the dorsolateral part, and the *ventral nucleus* in the ventromedial part. The ventral nucleus is subdivided into anterior, intermediate and posterior groups. The posterior group is further subdivided into the posterolateral and posteromedial groups.



Figs 8.11a and b: (a) Location of thalamus in the cerebral hemisphere, and (b) three-dimensional view of thalamus

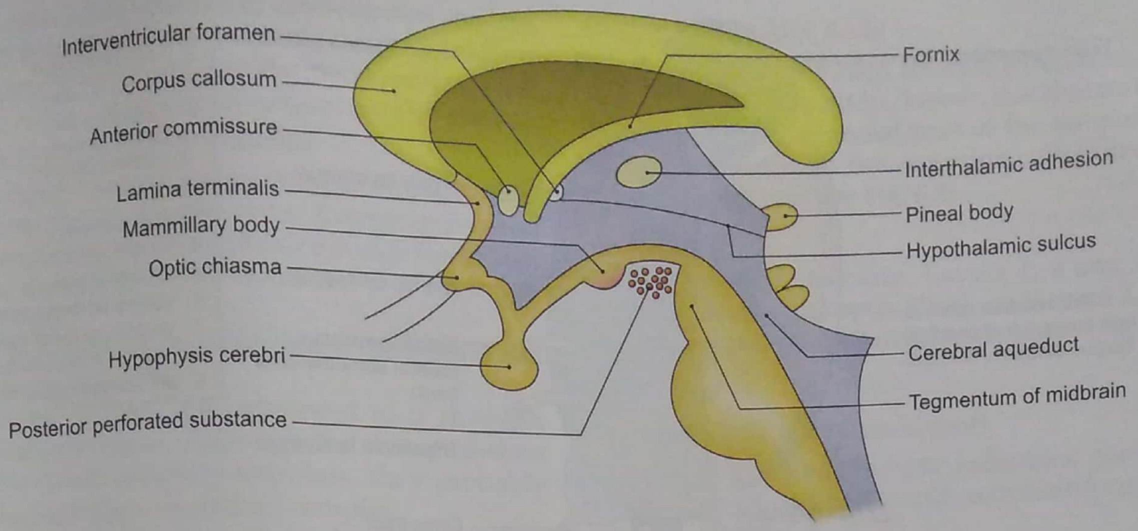


Fig. 8.12: Thalamus and hypothalamus as seen in sagittal section

Table 8.4: Connection of thalamus

Name	*Afferents*	*Efferents*	*Functions*
Anterior nucleus (Fig. 8.13)	Mammillothalamic tract	To cingulate gyrus (Fig. 8.15)	Relay station for hippocampal impulses
Medial nucleus	From hypothalamus, frontal lobe in front of area 6, corpus striatum, and other thalamic nuclei	To same parts from which the afferents are received	Relay station for visceral impulses
Lateral nuclei: Lateral dorsal, lateral posterior and pulvinar	From precuneus and superior parietal lobule; also from ventral and medial nuclei Temporal and occipital lobes	To precuneus and superior parietal lobule Temporal and occipital lobes	Correlative in function
Ventral nuclei: Ventral anterior	From globus pallidus (subthalamic fasciculus)	To areas 6 and 8 of cortex (Fig. 8.18)	Relay station for striatal impulses
Ventral lateral	From cerebellum (dentatothalamic fibres) and red nucleus	To motor areas 4 and 6	Relay station for cerebellar impulses
Ventral posterolateral (Figs 8.14 and 8.15)	Spinal and medial lemnisci	To postcentral gyrus (areas 3, 1, 2)	Relay station for exteroceptive (touch, pain and temperature) and proprioceptive impulses from body, except face and head
Ventral posteromedial (Fig. 8.15)	Trigeminal and solitariothalamic lemnisci	To postcentral gyrus (areas 3, 1, 2)	Relay station for impulses from the face, head and taste impulses
Intralaminar, midline, and reticular nuclei (Fig. 8.11)	Reticular formation of brain stem	To all parts of cerebral cortex	Participate in arousal reactions
Centromedian nucleus (Fig. 8.13)	From parts of corpus striatum; collaterals from spinal, medial, trigeminal lemnisci, ascending reticulothalamic fibres. Impulses from areas 4, 6 of cerebral cortex	Not connected to cerebral cortex, connected to other thalamic nuclei, corpus striatum	Receive pain fibres
Medial geniculate body	Auditory fibres from inferior colliculus	Primary auditory areas 41, 42 (Fig. 8.18)	Relay station for auditory impulses
Lateral geniculate body	Optic tract	Primary visual cortex area 17	Relay station for visual impulses

4 *Intralaminar nuclei* including *centromedian nucleus* (located in the internal medullary lamina), midline nuclei (periventricular grey on the medial surface) and reticular nuclei (on the lateral surface) are also present.

Connections and functions of thalamus

Afferent impulses from a large number of subcortical centres converge on the thalamus. Exteroceptive and proprioceptive impulses ascend to it through the medial lemniscus, the spinothalamic tracts and the trigemino-thalamic tracts.

Visual and auditory impulses reach the medial and lateral geniculate bodies.

Sensations of taste are conveyed to it through solitariothalamic fibres. Although the thalamus does not receive direct olfactory impulses, they probably reach it through the amygdaloid complex.

Visceral information is conveyed from the hypothalamus and probably through the reticular formation.

In addition to these afferents, the thalamus receives profuse connections from all parts of the cerebral cortex, the cerebellum and the corpus striatum. The thalamus is, therefore, regarded as a *great integrating centre* where information from all these sources is brought together. This information is projected to almost the whole of the cerebral cortex through profuse thalamocortical projections. Efferent projections also reach the corpus striatum, the hypothalamus and the reticular formation.

Besides its integrating function, the thalamus has some degree of ability to perceive exteroceptive sensations, especially pain. The connections and functions of nuclei of thalamus are shown in Table 8.4.

Metathalamus (Part of Thalamus)

The metathalamus consists of the medial and lateral geniculate bodies, which are situated on each side of the midbrain, below the thalamus.

Medial Geniculate Body

It is an oval elevation situated just below the pulvinar of the thalamus and lateral to the superior colliculus. The inferior brachium connects the medial geniculate body to the inferior colliculus. The connections of the medial geniculate body are as follows (*see* Fig. 6.8).

Afferents

(1) Lateral lemniscus, (2) fibres from both inferior colliculi, and (3) ascending reticular pathway.

Efferents

1 It gives rise to the acoustic (auditory) radiation going to the auditory area of the cortex (in the temporal lobe) through the sublentiform part of the internal capsule.

2 To secondary somatosensory area.

Function

Medial geniculate body is the last relay station on the pathway of auditory impulses to the cerebral cortex.

Lateral Geniculate Body

It is a small oval elevation situated anterolateral to the medial geniculate body, below the thalamus. It is overlapped by the medial part of the temporal lobe, and is connected to the superior colliculus by the superior brachium (*see* Fig. 6.8).

Structure

It is six-layered structure. Layers 1, 4 and 6 (pink) receive contralateral optic fibres, and layers 2, 3 and 5 (light blue) receive ipsilateral optic fibres (Fig. 8.16).

Connections

Afferents: Optic tract (lateral root).

Efferents: It gives rise to optic radiations going to the visual area of cortex through retrolentiform part of internal capsule.

Function

Lateral geniculate body is the last relay station on the visual pathway to the occipital cortex.

CLINICAL ANATOMY

- Lesions of the thalamus cause impairment of all types of sensibilities; joint sense (posture and passive movements) being the most affected.
- The thalamic syndrome (occurs due to vascular impairment) is characterized by disturbances of sensations, hemiplegia, or hemiparesis together with hyperaesthesia and severe spontaneous pain. Pleasant as well as unpleasant sensations or feelings are exaggerated. It is associated with abnormal movements like choreoathetosis.
- Damage to medial nucleus of thalamus results in decrease in tension aggression and anxiety. It increases forgetfulness.

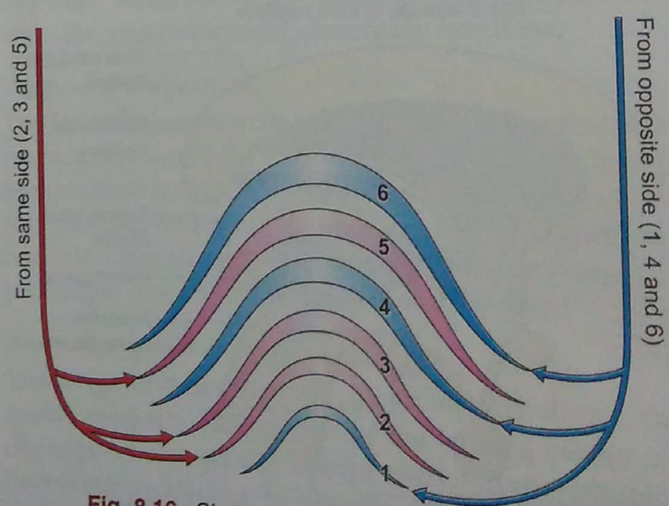


Fig. 8.16: Six layers of lateral geniculate body

Epithalamus

The epithalamus (Fig. 8.17) occupies the caudal part of the roof of the diencephalon and consists of:

1. The right and left habenular nuclei, each situated beneath the floor of the corresponding habenular trigone.
2. The pineal body or epiphysis cerebri.
3. The habenular commissure.
4. The posterior commissure.

Habenular Nucleus

The nucleus lies beneath the floor of the habenular trigone. The trigone is a small, depressed triangular area, situated above the superior colliculus and medial to the pulvinar of the thalamus. Medially, it is bounded by the stria medullaris thalami and stalk of the pineal body. The habenular nucleus forms a part of the limbic system.

Afferents

- Hypothalamus
- Amygdaloid body
- Hippocampus

Efferents: To interpeduncular nucleus

Functions: Acts as nodal point for convergence of basic emotional drives.

Pineal Body/Pineal Gland

The pineal (Latin *pine, cone*) body is a small, conical organ, projecting backwards and downwards between the two superior colliculi. It is placed below the splenium of the corpus callosum, but is separated from it by the tela choroidea of the third ventricle.

It consists of a conical *body* about 8 mm long, and a *stalk* or *peduncle* which divides anteriorly into two laminae separated by the pineal recess of the third ventricle. The superior lamina of the stalk contains the habenular commissure; and the inferior lamina contains the posterior commissure (Fig. 8.17).

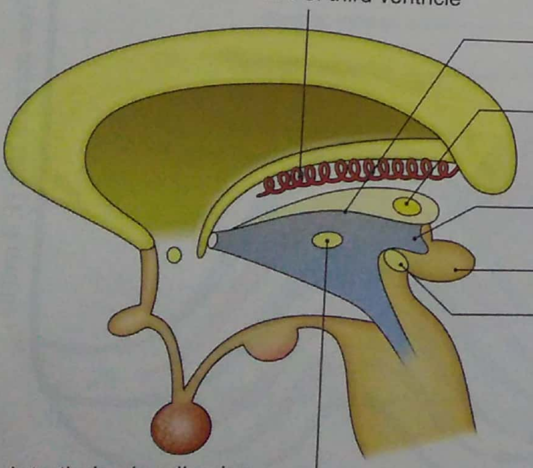


Fig. 8.17: Components of the epithalamus

Morphological Significance

In many reptiles, the epiphysis cerebri is represented by a double structure. The anterior part (*parapineal organ*) develops into the pineal or parietal eye. The posterior part is glandular in nature. The human pineal body represents the persistent posterior glandular part only. The parietal eye has disappeared.

Structure

The pineal gland is composed of two types of cells, pinealocytes and neuroglial cells, with a rich network of blood vessels and sympathetic fibres. The vessels and nerves enter the gland through the connective tissue septa which partly separate the lobules. Sympathetic ganglion cells may be present.

Calcareous concretions are constantly present in the pineal after the 17th year of life and may form aggregations (*brain sand*). Spaces or cysts may also be present. Pineal gland has no neural tissue in it.

Functions

The pineal body has for long been regarded as a vestigial organ of no importance. Recent investigations have shown that, it is an endocrine gland of great importance. It produces hormones that may have an important regulatory influence on many other endocrine organs (including the adenohypophysis, the neurohypophysis, the thyroid, the parathyroids, the adrenal cortex and medulla, and the gonads). The best known hormone is melatonin which causes changes in skin colour in some species. The synthesis and discharge of melatonin is remarkably influenced by exposure of the animal to light and is more during dark period.

Hypothalamus

The hypothalamus is a part of the diencephalon (Fig. 8.18). It lies in the floor and lateral wall of the third ventricle. It has been designated as the head ganglion of the autonomic nervous system because it takes part in the control of many visceral and metabolic activities of the body.

Anatomically, it includes:

a. The floor of the third ventricle, or structures in the interpeduncular fossa.
b. The lateral wall of the third ventricle below the hypothalamic sulcus.

Boundaries

As seen on the base of the brain, the hypothalamus is bounded *anteriorly* by the posterior perforated substance; and *on each side* by the optic tract and crus cerebri (Fig. 8.4).

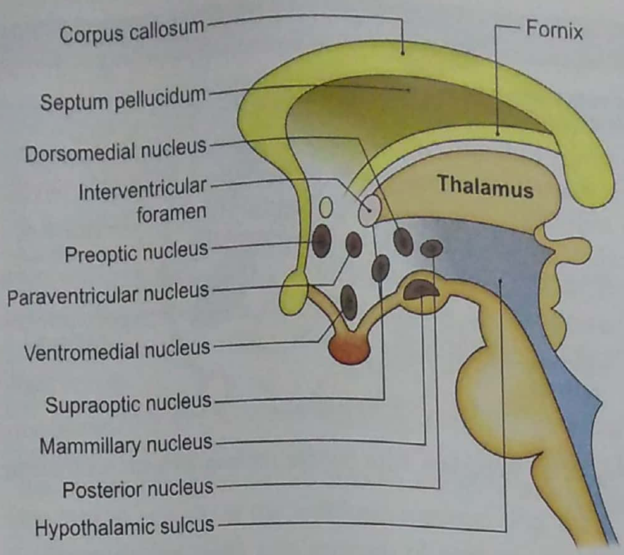


Fig. 8.18: Nuclei of medial zone of hypothalamus

As seen in a sagittal section of the brain, it is bounded *anteriorly* by the lamina terminalis; *inferiorly* by the floor of the third ventricle (from the optic chiasma to the posterior perforated substance); and *posterosuperiorly* by the hypothalamic sulcus.

Parts of the Hypothalamus

The hypothalamus is subdivided into optic, tuberal and mammillary parts. The nuclei present in each part are as follows:

Optic part

1 Preoptic and supraoptic nuclei.
2 Paraventricular nucleus, just above the supraoptic nucleus and lateral nucleus in lateral zone.
3 Suprachiasmatic nucleus—above the optic chiasma.

Tuberal part

4 Ventromedial nucleus.
5 Dorsomedial nucleus.
6 Tuberal nucleus, lateral to the ventromedial nucleus.
7 Arcuate nucleus—in floor of third ventricle.

Mammillary part

8 Posterior nucleus, caudal to the ventromedial and dorsomedial nuclei and mammillary nucleus.
9 Lateral nucleus, lateral to the posterior nucleus.

The nuclei 3, 4 and 6 (medial) are separated from nuclei 5 and 7 (lateral) by the column of the fornix, the mammillothalamic tract and the fasciculus retroflexus.

Important Connections

Afferents

The hypothalamus receives visceral sensations through the spinal cord and brain stem (reticular formation). It is also connected to several centres associated with olfactory pathways, including the piriform cortex, cerebellum; and retina.

Efferents

1 Supraoptico-hypophyseal tract from the optic nuclei to the pars posterior, the pars tuberalis and the pars intermedia of the hypophysis cerebri.
2 Mammillothalamic tract.
3 Mammillotegmental tract (periventricular system of fibres).
4 Tubero-infundibular tract.

Functions of Hypothalamus

The hypothalamus is a complex neuroglandular mechanism concerned with regulation of visceral and vasomotor activities of the body. Its functions are as follows:

Endocrine control

By forming *releasing hormones* or *release inhibiting hormones*, the hypothalamus regulates secretion of thyrotropin (TSH), corticotropin (ACTH), somatotropin (STH), prolactin, luteinizing hormone (LH), follicle-stimulating hormone (FSH) and melanocyte-stimulating hormone, by the pars anterior of the hypophysis cerebri.

Neurosecretion

Oxytocin and vasopressin (antidiuretic hormone, ADH) are secreted by the hypothalamus and transported to the infundibulum and the posterior lobe of the hypophysis cerebri.

General autonomic effect

The anterior parts of the hypothalamus chiefly mediate parasympathetic activity; and the posterior parts, chiefly mediate sympathetic activity, but the effects often overlap. Thus the hypothalamus controls cardiovascular, respiratory and alimentary functions.

Temperature regulation

The hypothalamus maintains a balance between heat production and heat loss of the body. Raised body temperature is decreased through vasodilation, sweating, panting and reduced heat production. Lowered body temperature is elevated by shivering and in prolonged cases by hyperactivity of the thyroid.

Regulation of food and water intake

The *hunger* or *feeding centre* is placed laterally, the *satiety centre*, medially. Stimulation of the feeding centre or damage of the satiety centre causes hyperphagia (overeating) leading to obesity. Stimulation of the satiety centre or damage of the feeding centre causes hypophagia or even aphagia and death from starvation.

The *thirst or drinking centre* is situated in the lateral part of the hypothalamus. Its stimulation causes copious drinking and overhydration.

Sexual behaviour and reproduction

Through its control of the anterior pituitary, the hypothalamus controls gametogenesis, various reproductive cycles (uterine, ovarian, etc.) and the maturation and maintenance of secondary sexual characteristics.

Through its connections with the limbic system, it participates in the elementary drives associated with food (hunger and thirst) and sex.

Biological clocks

Many tissues and organ-systems of the body show a cyclic variation in their functional activity during the 24 hours of a day (circadian rhythm). Sleep and wakefulness is an outstanding example of a circadian rhythm. Wakefulness is maintained by the *reticular activating system*. Sleep is produced by the *hypnogenic zones*, mainly of the thalamus and hypothalamus and partly by the brain stem. Lesions of the anterior hypothalamus seriously disturb the rhythm of sleep and wakefulness.

Emotion, fear, rage, aversion, pleasure and reward

These faculties are controlled by the hypothalamus, the limbic system and the prefrontal cortex.

CLINICAL ANATOMY

Lesions of the hypothalamus give rise to one of the following syndromes.

- Obesity: Frolich's syndrome, or Laurence-Moon-Biedl syndrome.
- Diabetes insipidus.
- Diencephalic autonomic epilepsy. This is characterized by flushing, sweating, salivation, lacrimation, tachycardia, retardation of respiratory rate, unconsciousness, etc.
- Sexual disturbance. Either precocity or impotence.
- Disturbance of sleep. Somnolence (persistent sleep), or narcolepsy (paroxysmal sleep).
- Hyperglycaemia and glycosuria.
- Acute ulcerations in the upper part of the gastro-intestinal tract.

Subthalamus

The subthalamus lies between the midbrain and thalamus, medial to internal capsule and the globus pallidus (Fig. 8.19). It consists of the following:

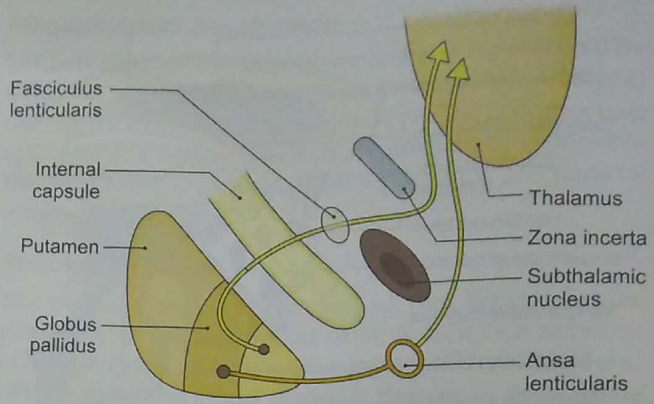


Fig. 8.19: Important fibre bundle running through subthalamic region

Grey Matter

1. The cranial ends of the red nucleus and substantia nigra extend into it.
2. Subthalamic nucleus.
3. Zona incerta.

White Matter

1. Cranial ends of lemnisci, lateral to the red nucleus.
2. Dentatothalamic tract along with the rubrothalamic fibres.
3. Ansa lenticularis (ventral) (Fig. 8.22).
4. Fasciculus lenticularis (dorsal).
5. Subthalamic fasciculus (intermediate fibres).

The *subthalamic nucleus* is biconvex (in coronal section) and is situated dorsolateral to the red nucleus and ventral to the zona incerta. From its connections, it appears to be an important site for integration of a number of motor centres.

The *zona incerta* is a thin lamina of grey matter situated between the thalamus and the subthalamic nucleus. Laterally, it is continuous with the reticular nucleus of the thalamus. Its activity influences drinking of water.

CLINICAL ANATOMY

Discrete lesions of the subthalamic nucleus result in *hemiballismus* characterised by involuntary choreiform movements on the opposite side of the body. The condition is abolished by ablation of the globus pallidus or of its efferent tracts, the anterior ventral nucleus of the thalamus, area 4 of the cerebral cortex, or of the corticospinal tract. From these facts, it appears that the subthalamic nucleus has an inhibitory control on the globus pallidus and on the cerebral cortex.