Cerebral Cortex

■ INTRODUCTION

Cerebral cortex is also called **pallidum** and it consists of two hemispheres. Surface area of cerebral cortex in human beings is 2.2 sq m.

Both the **cerebral hemispheres** are separated by a deep **vertical fissure** (deep furrow or groove). The separation is complete anteriorly and posteriorly. But in middle portion, the fissure extends only up to corpus callosum. **Corpus callosum** is the broad band of commissural fibers, connecting the two hemispheres.

Surface of the cerebral cortex is characterized by complicated pattern of sulci (singular = sulcus) and

gyri (singular = gyrus). Sulcus is a slight depression or groove and gyrus is a raised ridge.

■ HISTOLOGY OF CEREBRAL CORTEX

■ LAYERS OF CEREBRAL CORTEX

Cerebral cortex consists of **gray matter** that surrounds the deeper **white matter.** It is formed by different types of nerve cells along with their processes and neuroglia. It is not uniform throughout. It is thickest, i.e. 4.5 cm at the precentral gyrus and thinnest at frontal and occipital poles. According to **Economo,** the cerebral cortex is formed by six layers of structures. Following are the layers from outside to inside:

1. *Molecular or Plexiform Layer*

Molecular layer has few small fusiform cells. It also contains dendrites or axons from cells of deeper layers.

2. *External Granular Layer*

External granular layer consists of large number of closely packed small cells, which are round, polygonal or triangular in shape. Dendrites of these cells pass into molecular layer. Axons end in the deeper layers. Some axons enter white substance of the hemisphere.

3. *Outer Pyramidal Layer*

Outer pyramidal layer is formed by **pyramidal cells,** which are of two sizes. Medium sized pyramidal cells are in the outer portion and larger pyramidal cells are in deeper portion.

4. *Internal Granular Layer*

Like external granular layer, this layer also has closely packed smaller cells, which are **stellate type.** But, the nerve fibers are more in this layer than in external granular layer. This layer contains many **horizontal fibers,** which appear as a white strip known as **outer strip.**

5. *Ganglionic Layer or Internal Pyramidal Layer*

Ganglionic layer or internal pyramidal layer consists of **pyramidal cells** of graded sizes. It is well developed in the precentral (motor) cortex. Pyramidal cells in this region are otherwise known as **Betz cells** or **giant cells.** This layer also contains **cells of Martinotti.** Martinotti cells are peculiar in that their axons pass outward towards the surface of the cortex.

6. *Fusiform Cell Layer*

Fusiform cell layer is in contact with white matter of cerebral hemisphere. It is composed of closely packed small spindle-shaped cells.

■ PARTS OF CEREBRAL CORTEX

Cerebral cortex is divided into two parts based on phylogeny (evolutionary development of a species):

1. Neocortex
2. Allocortex.

1. *Neocortex*

Neocortex is the phylogenetically new structure of cerebral cortex. It is also called **isocortex** or **neopallium.**

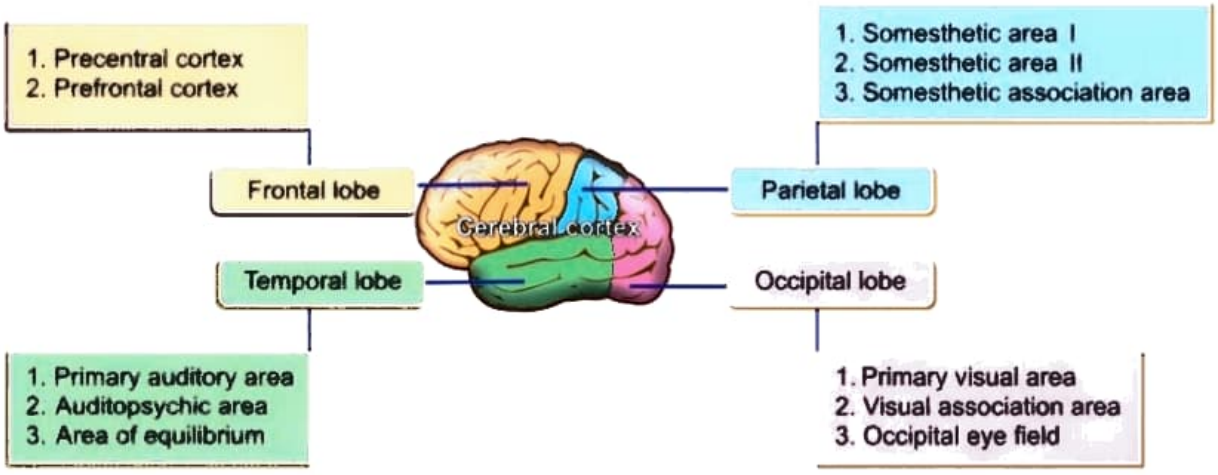

FIGURE 152.1: Parts of cerebral cortex

This part forms the major portion of cerebral cortex.

Part of the cerebral cortex that has all six layers of structures is called neocortex.

2. *Allocortex*

Allocortex is the phylogenetically oldest structure of cerebral cortex. It has less than six layers of structures. It is divided into two divisions namely, **archicortex** and **paleocortex,** which form the parts of **limbic system** (Chapter 153).

■ LOBES OF CEREBRAL CORTEX

In each hemisphere, there are three surfaces lateral, medial and inferior surfaces. **Neocortex** of each cerebral hemisphere consists of four lobes (Figs. 152.1 to 152.3):

1. Frontal lobe
2. Parietal lobe
3. Occipital lobe
4. Temporal lobe.

Lobes of each hemisphere are demarcated by four main fissures and sulci:

1. **Central sulcus** or **Rolandic fissure** between frontal and parietal lobes
2. **Parieto-occipital sulcus** between parietal and occipital lobe
3. **Sylvian fissure** or **lateral sulcus** between parietal and temporal lobes
4. **Callosomarginal fissure** between temporal lobe and limbic area.

■ CEREBRAL DOMINANCE

Cerebral dominance is defined as the dominance of one cerebral hemisphere over the other in the control of cerebral functions. Both the cerebral hemispheres are not functionally equivalent. Some functional asymmetries are well known.

■ CEREBRAL DOMINANCE AND HANDEDNESS

Cerebral dominance is related to handedness, i.e. preference of the individual to use right or left hand. More than 90% of people are **right handed.** In these individuals, the left hemisphere is dominant and it controls the analytical process and language related functions such as speech, reading and writing. Hence, left hemisphere of these persons is called **dominant or categorical hemisphere.**

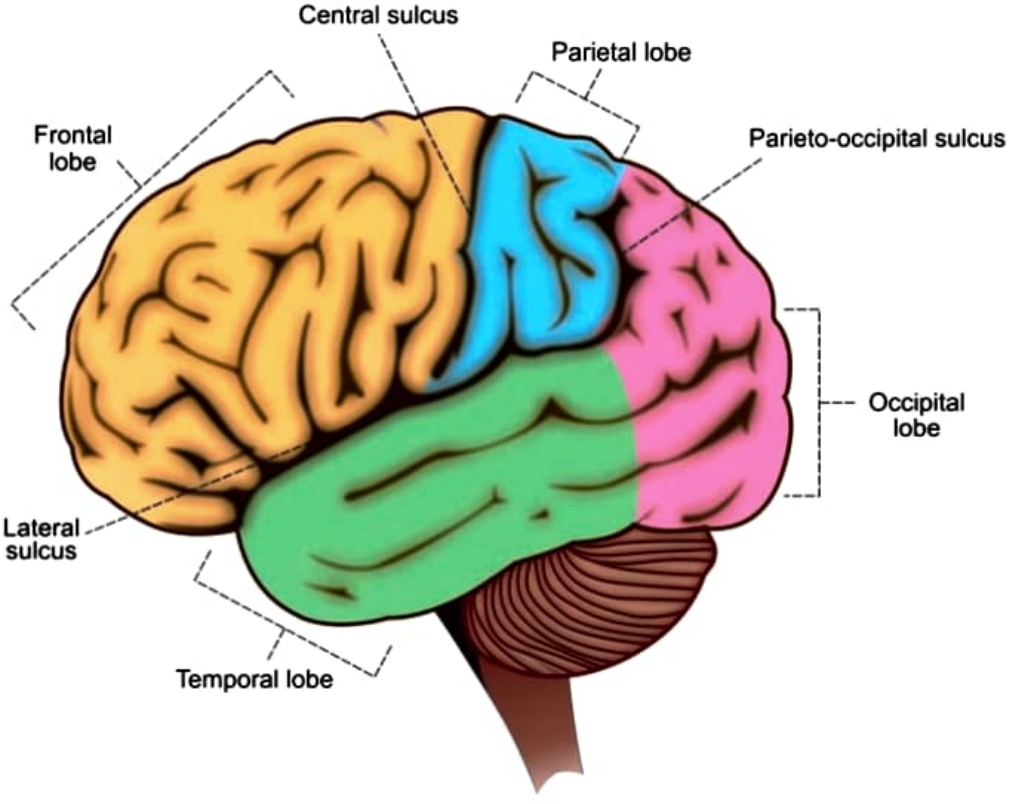

FIGURE 152.2: Lobes of cerebral cortex

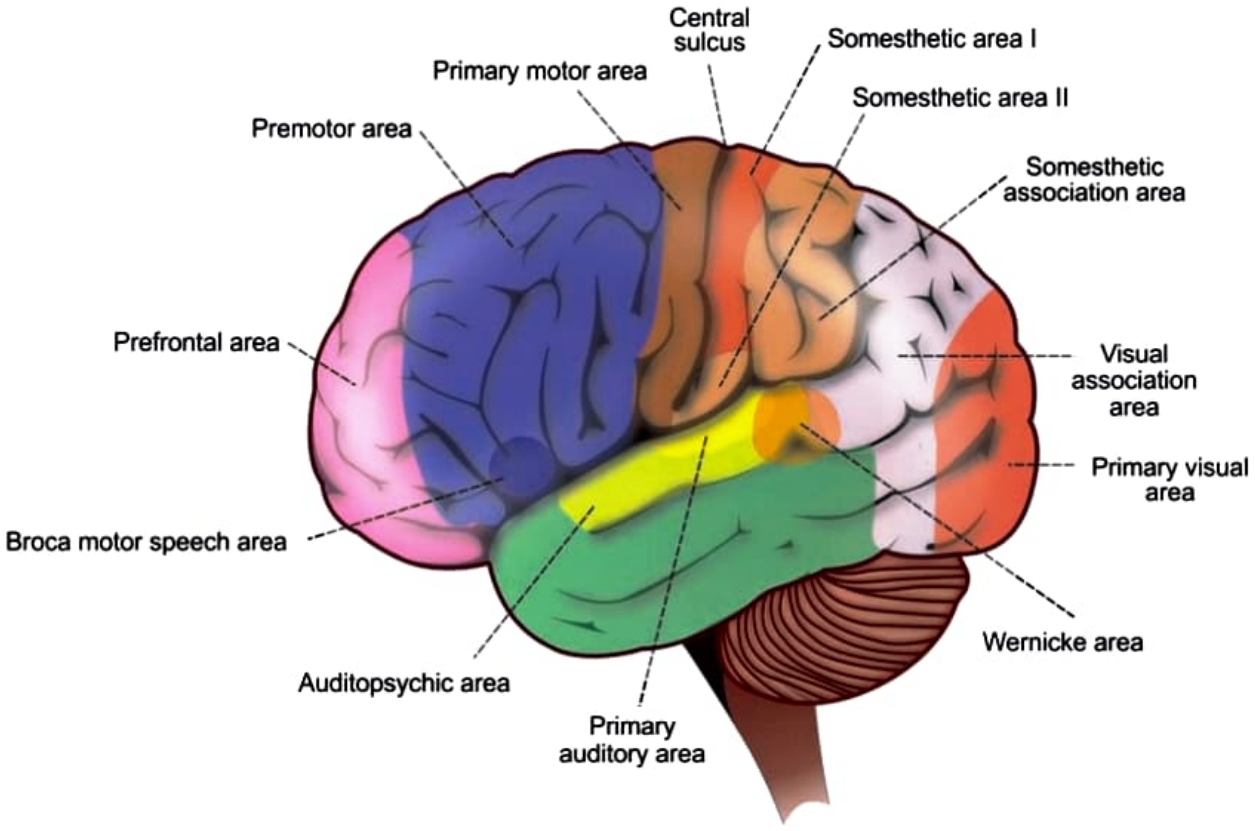

FIGURE 152.3: Functional regions on lateral surface of cerebral cortex

Right hemisphere is called **representational hemisphere** since it is associated with artistic and visuospatial functions like judging the distance, determining the direction, recognizing the tones, etc.

Lesion in dominant hemisphere leads to language disorders. Lesion in representational hemisphere causes only mild effects like astereognosis.

Left hemisphere is the dominant hemisphere in about 75% of the right-handed persons. In the remaining left-handed persons, right hemisphere controls the language function. Some of these persons do not have dominant hemisphere.

■ BRODMANN AREAS

Brodmann area is a region of cerebral cortex defined on the basis of its **cytoarchitecture.** Cytoarchitecture means organization of cells. Brodmann areas were originally defined and numbered in 1909 by **Korbinian Brodmann** depending upon the laminar organization of neurons in the cortex. Some of these areas were given specific names based on their functions. During the period of a century Brodmann areas had been extensively discussed and renamed.

Functions of primary motor area

Primary motor area is concerned with initiation of voluntary movements and speech.

Function of area 4

Area 4 is the center for movement, as it sends all efferent (corticospinal) fibers of primary motor area. Through the fibers of corticospinal tracts, area 4 activates the lower motor neurons in the spinal cord. It activates both **α-motor neurons** and **γ-motor neurons** simultaneously by the process called **coactivation** (Chapter 157).

Activation of α-motor neurons causes contraction of **extrafusal fibers** of the muscles. Activation of γ-motor neurons causes contraction of **intrafusal fibers** leading to increase in muscle tone.

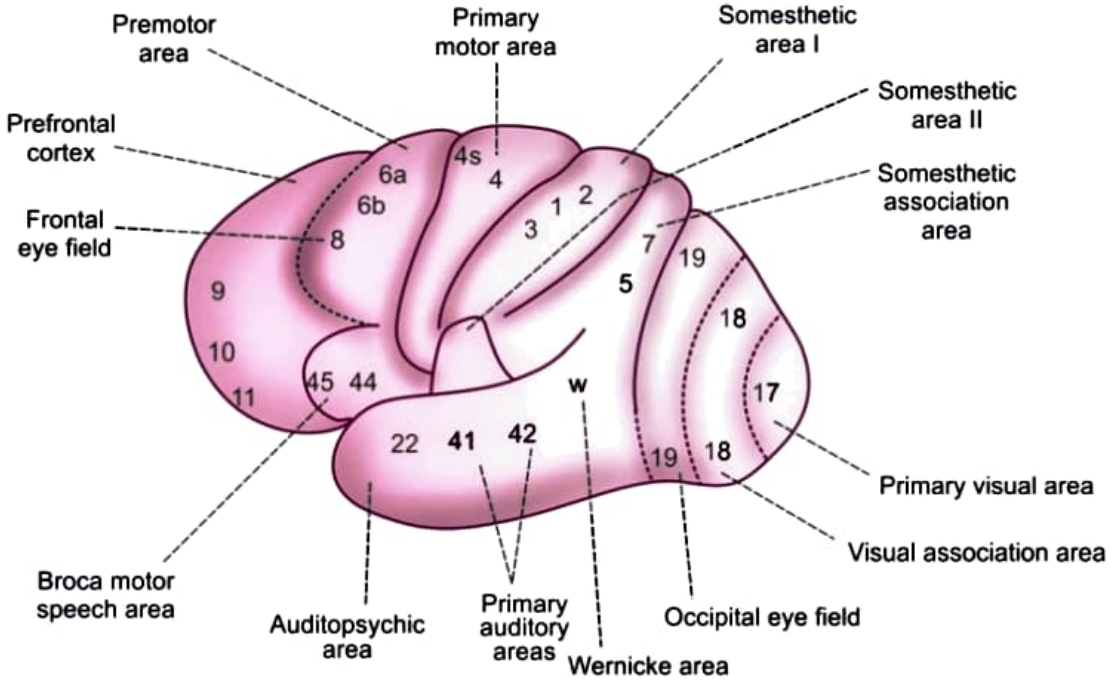

FIGURE 152.4: Lateral surface of cerebral cortex

Area 4 is concerned with contraction of discrete muscles. It sends motor signals to the facial muscles of both sides (bilateral) and the other muscles of the opposite side (contralateral).

Area 4S

Area 4S is called **suppressor area.** It forms a narrow strip anterior to area 4. It scrutinizes and suppresses the extra impulses produced by area 4 and inhibits exaggeration of movements.

2. *Premotor Area*

Premotor area includes areas 6, 8, 44 and 45. The premotor area is anterior to primary motor area in the precentral cortex. The premotor area is concerned with control of postural movements by sending motor signals to **axial muscles** (muscles near the midline of the body).

Functions of area 6

Area 6 has two functions:

i. It is concerned with **coordination of movements** initiated by area 4. It helps to make the skilled movements more accurate and smooth.
ii. It is believed to be the **cortical center** for **extra-pyramidal system.**

Function of area 8

Frontal eye field is concerned with **conjugate movement** of eyeballs (Chapter 165). This area initiates voluntary scanning movements of eyeballs and it is independent of visual stimuli. It is also responsible for opening and closing of eyelids, pupillary dilatation and lacrimation.

Broca area

Broca area is the **motor area for speech.** It includes areas 44 and 45. Broca area is present in left hemisphere (dominant hemisphere) of right-handed persons and in the right hemisphere of left-handed persons. It is a special region of premotor cortex situated in inferior frontal gyrus. Area 44 is situated in pars triangularis and 45 in pars opercularis of this gyrus.

Function of Broca area

Broca area is responsible for movements of tongue, lips and larynx, which are involved in **speech.**

Effect of lesion of Broca area

Lesion in Broca area leads to **aphasia** (Chapter 162).

3. *Supplementary Motor Area*

Supplementary motor area is situated in medial surface of frontal lobe rostral to primary motor area. Various motor movements are elicited by electrical stimulation of this area like raising the contralateral arm, turning the head and eye and movements of synergistic muscles of trunk and legs.

Function of supplementary motor area

Exact function of this area is not understood clearly. It is suggested that it is concerned with **coordinated skilled movements.**

■ PREFRONTAL CORTEX OR ORBITOFRONTAL CORTEX

Prefrontal cortex is the anterior part of frontal lobe of cerebral cortex, in front of areas 8 and 44. It occupies the medial, lateral and inferior surfaces and includes orbital gyri, medial frontal gyrus and the anterior portions of superior, middle and inferior frontal gyri.

Areas present in prefrontal cortex are 9, 10, 11, 12, 13, 14, 23, 24, 29 and 32. Areas 12, 13, 14, 23, 24, 29 and 32 are in medial surface (Table 152.1). Areas 9, 10 and 11 are in lateral surface.

Functions of Prefrontal Cortex

Earlier, this area was considered as inexcitable to electrical stimulation. Hence, it was called the **silent area** or **association area.** But, now it is known that the stimulation of this area with low voltage electrical stimulus causes changes in the activity of digestive, cardiovascular, respiratory and excretory systems and other autonomic functions. It also causes fear. Various functions of prefrontal cortex are:

1. It forms the center for the higher functions like emotion, learning, memory and social behavior. **Short-term memories** are registered here.
2. It is the center for **planned actions**
3. This area is the **seat of intelligence;** so, it is also called the **organ of mind**
4. It is responsible for the **personality** of the individuals
5. Prefrontal cortex is responsible for the various **autonomic changes** during emotional conditions, because of its connections with hypothalamus and brainstem.

TABLE 152.1: Areas and connections of frontal lobe

Areas		Afferent fibers from	Efferent fibers to
Precentral cortex	Primary motor areas 4, 4s	1. Cerebellum (Dentate nucleus – via red nucleus) 2. Thalamus	1. Corticospinal tract 2. Pons 3. corpus striatum 4. Red nucleus 5. Thalamus 6 Subthalamus 7. Reticular formation
	Premotor areas 6, 8, 44, 45		
	Supplementary area		
Prefrontal cortex	Areas 9, 10, 11, 12, 13, 14, 29, 23, 24, 32	1. Thalamus 2. Hypothalamus 3. Corpus striatum 4. Amygdala 5. Midbrain	1. Thalamus 2. Hypothalamus 3. Tegmentum 4. Caudate nucleus 5. Temporal lobe

■ PARIETAL LOBE

Parietal lobe extends from central sulcus and merges with occipital lobe behind and temporal lobe below. This lobe is separated from occipital lobe by parieto-occipital sulcus and from temporal lobe by Sylvian sulcus. Parietal lobe is divided into three functional areas:

A. Somesthetic area I
B. Somesthetic area II
C. Somesthetic association area.

In addition to these three areas, a part of sensory motor area is also situated in parietal lobe (see below).

■ SOMESTHETIC AREA I

Somesthetic area I is also called **somatosensory area** I or primary somesthetic or primary sensory area. It is present in the posterior lip of central sulcus, in the postcentral gyrus and in the paracentral lobule.

Areas of Somesthetic Area I

Somesthetic area I has three areas, which are called areas 3, 1 and 2. Anterior part of this forms area 3 and posterior part forms areas 1 and 2.

Functions of Somesthetic Area I

1. Somesthetic area I is responsible for perception and integration of **cutaneous** and **kinesthetic sensations.** It receives sensory impulses from cutaneous receptors (touch, pressure, pain, temperature) and proprioceptors of opposite side through thalamic radiation. Area 1 is concerned with sensory perception. Areas 3 and 2 are involved in the integration of these sensations.
2. This area sends **sensory feedback** to the premotor area
3. This area is also concerned with the movements of head and eyeballs
4. Discriminative functions: In addition to perception of cutaneous and kinesthetic sensation, this area is also responsible for recognizing the **discriminative features** of sensations.
   Discriminative functions are:
   i. Spatial recognition: Tactile localization, two point discrimination and recognition of position and passive movements of limbs
   ii. Recognition of intensity of different stimuli
   iii. Recognition of similarities and differences between the stimuli.

with perception of sensation. Thus, the sensory parts of body have two representations, in somesthetic area I and area II.

■ SOMESTHETIC ASSOCIATION AREA

Somesthetic association area is situated posterior to postcentral gyrus, above the auditory cortex and in front of visual cortex. It has two areas, 5 and 7.

Functions of Somesthetic Association Area

Somesthetic association area is concerned with synthesis of various sensations perceived by somesthetic area I. Thus, the somesthetic association area forms the center for combined sensations like stereognosis. Lesion of this area causes astereognosis.

Sensory Motor Area

Sensory area of cortex is not limited to postcentral gyrus in parietal lobe. It extends anteriorly into motor area in precentral gyrus of frontal lobe. Similarly, the motor area is extended from precentral gyrus posteriorly into postcentral gyrus.

Thus, the precentral and postcentral gyri are knit together by association neurons and are functionally inter-related. So, this area is called sensory motor area.

Function of sensory motor area is to store the timing and programming of various sequential movements of complicated skilled movements, which are planned by neocerebellum (Table 152.2).

■ SOMESTHETIC AREA II

Somesthetic area II is situated in postcentral gyrus below the area of face of somesthetic area I. A part of this is buried in Sylvian sulcus. It is also known as secondary somesthetic area or somatosensory area II.

Functions of Somesthetic Area II

Somesthetic area II receives sensory impulses from somesthetic area I and from thalamus directly. Though the exact role of this area is not clear, it is concerned

■ TEMPORAL LOBE

Temporal lobe of cerebral cortex includes three functional areas (Table 152.3):

A. Primary auditory area
B. Secondary auditory area or auditopsychic area
C. Area for equilibrium.

■ PRIMARY AUDITORY AREA

Primary auditory area includes:

1. Area 41
2. Area 42
3. Wernicke area.

TABLE 152.2: Areas and connections of parietal lobe

Areas	Afferent fibers from	Efferent fibers to
Somesthetic area I – 3, 1, 2 (Primary somesthetic area)	Thalamus	Premotor area
Somesthetic area II	Somesthetic area I Thalamus	Motor area
Somesthetic association areas 5, 7	Somesthetic area I	Somesthetic area I

TABLE 152.3: Areas and connections of temporal lobe

Areas	Afferent fibers from	Efferent fibers to
Primary auditory areas 41, 42, Wernicke area Auditopsychic area 22 Area for equilibrium	1. Medial geniculate body via auditory radiation 2. Pulvinar	1. Medial geniculate body 2. Pulvinar

Areas 41 and 42 are situated in anterior transverse gyrus and lateral surface of superior temporal gyrus. Wernicke area is in upper part of superior temporal gyrus posterior to areas 41 and 42.

Functions of Primary Auditory Area

Primary auditory area is concerned with perception of auditory impulses, analysis of pitch and determination of intensity and source of sound.

Areas 41 and 42 are concerned only with the **perception** of auditory sensation (sound). Wernicke area is responsible for the **interpretation** of auditory sensation. It carries out this function with the help of secondary auditory area (area 22). Wernicke area is also responsible for understanding the auditory information about any word and sending the information to Broca area (Chapter 162).

■ SECONDARY AUDITORY AREA

Secondary auditory area occupies the superior temporal gyrus. It is also called or **auditopsychic area** or **auditory association** area. It includes area 22.

This area is concerned with interpretation of auditory sensation along with Wernicke area. It is also concerned with storage of memories of spoken words (Chapter 162).

■ AREA FOR EQUILIBRIUM

Area for equilibrium is in the posterior part of superior temporal gyrus. It is concerned with the maintenance of equilibrium of the body. Stimulation of this area causes dizziness, swaying, falling and feeling of rotation.

■ OCCIPITAL LOBE

Occipital lobe is called the **visual cortex.** Areas and connections of occipital lobe is given in Table 152.4.

TABLE 152.4: Areas and connections of occipital lobe

Areas	Afferent fibers from	Efferent fibers to
Primary visual area – 17	Lateral geniculate body	Superior colliculus Lateral geniculate body
Visual association area – 18		
Occipital eye field – 19		

■ AREAS OF VISUAL CORTEX

Occipital lobe consists of three functional areas:

1. Primary visual area (area 17)
2. Secondary visual area or visuopsychic area (area 18)
3. Occipital eye field (area 19).

Functions of Occipital Lobe

1. Primary visual area (area 17) is concerned with **perception** of visual sensation
2. Secondary visual area (area 18) is concerned with **interpretation** of visual sensation and storage of memories of visual symbols (Chapter 162)
3. Occipital eye field (area 19) is concerned with reflex **movement of eyeballs.** It is also concerned with associated movements of eyeballs while following a moving object. (Table 152.5).

TABLE 152.5: Functions of cortical lobes

Lobe				Functions
Frontal lobe	Precentral cortex	Primary motor area	Area 4	Initiates of movements
			Area 4S	Inhibits exaggeration of movements initiated by area 4
		Premotor area	Area 6	Coordinates movements initiated by area 4 Acts as higher center for extrapyramidal system
			Area 8	Frontal eye field Concerned with conjugate movements of eyeballs Concerned with voluntary movements of eyeballs
			Broca area: Areas 44 and 45	Initiates movements involved in speech; motor speech area
		Supplementary motor area	–	Concerned with coordinated skilled movements
	Prefrontal cortex	Areas 9, 10, 11, 12, 13, 14, 23, 24, 29 and 32		Concerned with emotion, learning, memory and social behavior Act as the center for planned actions Form seat of intelligence Initiate autonomic changes during emotional conditions
Parietal lobe	Somesthetic area I	Area 1		Perceives cutaneous and kinesthetic sensations
		Areas 3 and 2		Integrate cutaneous and kinesthetic sensations
		Areas 3, 2 and 1		Send feedback to premotor area Concerned with movements of head and eyeballs Concerned with recognition of discriminative features of sensations
	Somesthetic area II	–		Perceives cutaneous and kinesthetic sensations
	Somesthetic association area	Areas 5 and 7		Synthesize sensations perceived by somesthetic area I (forms the center for combined sensations)
Temporal lobe	Primary auditory area	Areas 41 and 42		Perceive auditory sensation
		Wernicke area		Interprets auditory sensation (along with area 22)
	Secondary auditory area	Area 22		Interprets auditory sensation (along with Wernicke area)
	Area for equilibrium	–		Concerned with maintenance of equilibrium of body
Occipital lobe	Primary visual area	Area 17		Perceives visual sensation
	Secondary visual area	Area 18		Interprets visual sensation
	Occipital eye field	Area 19		Concerned with reflex movement of eyeballs Concerned with associated movements of eyeballs while following a moving object