THE CEREBRAL CORTEX

Parcellation of the cerebral cortex

Brodman parcellated the human brain in 51 different fields, based upon its cytoarchitecture. For example, each of the various sensory modalities are represented within the cortex and each has a unique architecture. The primary cortical sensory areas receive relayed input from specific thalamic nuclei, which convey direct or indirect lemniscal afferents that are linked to the periphery. In the case of the visual modality, retinal ganglion cells project to the LGB which in turn gives rise to the optic radiation. This massive pathway terminates in Brodman's area 17, the primary visual cortex. In the case of the auditory modality, the MGB receives auditory input from the inferior colliculus and gives rise to the acoustic radiation that terminates in Brodman's areas 41 and 42, the primary auditory cortex. Lemniscal input carrying somatic sensory information for the entire body terminates in the ventrobasal complex of the thalamus which projects to Brodman's areas 3, 1 and 2. All of the primary sensory areas are characterized by conspicous cytoarchitectural fields that set them apart from other cortical areas. Most notable is a highly dense and granular LIV populated by small stellate neurons. These neurons are the major recipients of the thalamic relay that terminates in the primary sensory cortex.

The major motor-related areas of the cerebral cortex comprise Brodman's areas 4, 6 and 8 and similar to the primary sensory areas, these brain areas have a distinct cytoarchitecture. These areas form the so called agranular parts of the cerebral cortex, so named because they have poorly developed LIVs and a paucity of small neurons. Pyramidal cells predominate in this cortex and they are especially well developed in LII, V and VI.

Although the primary sensory and agranular motor fields are important functional areas, and distinct anatomical parts of the cerebral cortex, they constitute a rather small percentage of the total cerebral cortex in the human brain. A vast amount of the human cerebral cortex, which generally has been termed association cortex, would be best characterized as intermediate in structure, in other words, having both a population of smaller granule or stellate neurons and a discernible population of larger pyramidal shaped neurons. Six well-differentiated layers are seen: 1) a largely acellular molecular or plexiform zone adjacent to the pia mater forming LI; 2) a narrow, but clear, external granular layer of smaller cells forming LII; a wider outer pyramidal layer forming LIII; 4) a compact internal granular layer IV; 5) a conspicous layer of larger pyramids forming the internal pyramidal cell layer V; and 6) an intermixed or multiform layer forming layer VI. This laminar parcellation is valid for much of the non-agranular and non-primary sensory parts of the cerebral cortex, although there are substantial regional variations.

It is useful to divide the association cortices into two categories. One is the primary association cortices that are located in close proximity to the primary sensory cortices. These receive short cortico-cortical connections from the primary sensory cortices. Areas, such as Brodman's 18 and 19 for the visual modality and area 5 for somatic sensation, are committed to a single modality and deficits due to their destruction are purely unimodal. Each of the primary association areas then give rise to projections to other parts of the association cortex which have been referred to as secondary association areas. Secondary association areas project to certain frontal lobe areas and to limbic cortical areas. Sensory association areas may also send projections to a common cortical area where multimodal convergence occurs. Brodmann,s areas 9,10 and 46 in the frontal lobe and areas 39 and 40 in the parietal lobe are such multomodal association areas. This entire sequence of projections has been referred as the feed-forward system of cortical connections, and it is complemented by a feed-back system of connections.

The primary sensory cortices, the agranular motor cortices, and the association cortices can all be viewed as neo-or isocortex and they conform in a general sense to the six-layered pattern. Other cortical areas do not. For example, much of the cortex of the limbic lobe is best termed proisocortex. For example, LIV may be missing entirely or may be incipient, or LV and VI may merge together into an undifferentiated layer of cells. Brodmann's area 23 and 14 of the cingulate gyrus are good examples of proisocortex. The periallocortex is another atypical form of cortex. It is often characterized by an incomplete six-layered pattern, but it also has an unusual laminar distribution of neurons. For example, large and densely-packed neurons may be present in Lll, whereas this is typically seen in only the deeper layers of the iso- and proisocortex. The least typical of all cortical types is the allocortex. It has only two to three layers. The cortex of the hippocampus and olfacory cortical areas are the best examples of allocortex.

Survey of major cortical areas. Frontal, parietal, temporal, ocipital, limbic lobes

Frontal lobe. The sulcal limits that define the frontal lobe are the central sulcus, or fissura Rolando, posteriorly, and the lateral, or Svlvian fissure. ventrally. The precentral sulcus lies roughly parallel with the central sulcus, in a rostral position, and typically enables an unambiguous identification of the precentral gyrus (area 4) where motor representation, for the contralateral body musculature is mapped. Other major sulci of the frontal lobe include the superior frontal sulcus and the inferior frontal sulcus that divide the frontal cortex into superior, middle, and inferior frontal gyri. The inferior frontal gyrus is parcellated further by two important branches of the lateral fissure. One branch, which ascends vertically, is known as the anterior ascending branch of the lateral fissure, and between it and the ventral part of the precentral sulcus is the so-called pars opercularis (area 44). Another branch, the anterior horizontal sulcus extends in the direction of the frontal pole, and the cortical area between it and the anterior ascending sulcus forms the so-called pars triangularis (area 45). Areas 44 and 45 together form Broca's expressive speech area. Beneath the anterior horizontal branch of the lateral fissure is the orbital part of the frontal lobe which overlies the orbit.

Parietal lobe. The parietal lobe, unlike the frontal lobe, is not defined as precisely by primary sulci. Its anterior boundary is defined clearly by the central sulcus and a prominent postcentral sulcus is seen typically running parallel to it. Between the central and the postcentral sulcus is the postcentral gyrus where somatic sensation for the entire contralateral body surface, including the face, is mapped (areas 3,1 and 2). The posterior border of the parietal lobe is typically clearcut on the medial surface of the hemisphere where it is formed by the parieto-occipital sulcus. If this sulcus can be seen on the lateral surface of the hemisphere, a line connecting it to the pre-occipital notch on the ventral extent of the hemisphere provides an arbitrary approximation for the parietal boundary with the occipital lobe. The intraparietal sulcus is normally prominent in most specimens and courses more or less perpendicular to the postcentral sulcus. It divides the parietal lobe into a superior parietal lobule and an inferior parietal lobule. The inferior parietal lobule is important for sensory language functions and is formed by area 40, the supramarginal gyrus, and area 39, the angular gyrus. The former caps the posterior tip of the lateral fissure, whereas the latter, either caps or lies in close proximity to the posterior tip of the superior temporal sulcus.

Occipital lobe. Only the polar portion of the lateral surface of the hemisphere forms the occipital lobe. Most of the occipital lobe and much of the primary visual cortex (area 17) lies on the medial surface of the hemisphere.

Temporal lobe. The temporal lobe is bounded dorsally by the lateral fissure and extends posteriorly to the arbitrary line between the parieto-occipital sulcus and the pre-occipital notch. The

temporal lobe is expansive and is divisible into several regions by sulci that course in an antero-posterior direction. The superior temporal sulcus is a prominent feature, and parallels the lateral fissure for much of its course. The superior temporal gyrus lies between this sulcus and the lateral fissure. The auditory cortex, areas 41 and 42, are located on the upper bank of the superior temporal gyrus where it is mostly hidden from view in the depth of the lateral fissure. The inferior temporal sulcus separates the inferior temporal gyrus from the lateral occipitotemporal gyrus, while the collateral sulcus separates from the previous gyrus the medial occipitotemporal gyrus. The medial occipitotemporal gyrus can be devided into a more anterior, parahippocampal gyrus and a caudal lingual gurus. The uncus is a conspicous part of the anterior parahippocampal gyrus. It receives the vast majority of olfactory bulb projections via the lateral olfactory tract. It also contains the cortical amygdaloid nuclei and part of the hippocampal formation, which has become extruded from the temporal or inferior horn of the lateral ventricle. The remaining cortex of the anterior parahippocampal gyrus is the entorhinal cortex, area 28, which is connected intimately with the hippocampal formation.

Limbic lobe. In the 19th century, Broca called attention to the fact that the limbus or edge of the cerebral hemisphere formed a continuous ring of cortex around the corpus callosum and upper brainstem. He coined the term limbic lobe to set this area apart from the other lobes. MacLean in the nineteen fifties expanded this concept and added subcortical gray masses and various interconnecting pathways with the cortex of the limbic lobe into what he termed the "limbic system". The limbic lobe is purely cortical in terms of structure and contains nearly all of the non-isocortical areas of the cerebral hemisphere. Two major sulci aid in defining the limbic lobe. Anteriorly, and dorsally the cingulate sulcus separates the cingulate gyrus from the medial and dorsal parts of the frontal lobe. The lateral limit of the limbic lobe in the temporal area is formed by the collateral sulcus (the rostral part corresponds to the rhinal sulcus), which separates the parahippocampal gyrus from the lateral occipitotemporal gyrus.

The hippocampal formation, which is prominent part of the limbic lobe, is only barely visible from the external surface of the hemisphere. It is rolled up largely in the inferior horn of the lateral ventricle. The hippocampus appears as a curved cortical structure in the floor and medial wall of the temporal horn of the lateral ventricle. The hippocampus, the dentate gyrus, and the cortical area along the other side of the hippocampus, the subiculum, are reffered to as the hippocampal formation. Information from sensory cortical areas converges on the entorhinal cortex (EC) in the parahippocampal gyrus. The EC, in turn, project to the hippocampus and dentate gyrus. The cortical input to the hippocampus is mirrored by efferent projections from the hippocampus back to the cerebral cortex. Another well-known efferent pathway is the fornix. Through the fornix information from the hippocampal formation can reach a variety of subcortical structures, primarily the septum, the hypothalamus, and the anterior thalamic nuclei. The hippocampus has been implicated in spatial orientation mechanisms and may serve as a "cognitive map" which makes it possible for us to compare present situations with those experienced previously.

Jeffrey Cummings and his colleague's recent studies suggest that understanding the development and organization of the limbic system help to interpret diseases relevant to neuropsychiatry. Accordingly, the paleocortical limbic division (orbitofrontal, amygdala, anterior parahippocampus, insula, temporal pole, infracallosal cingulate) participate in implicit integration of affect, drives, visual feature analysis, social awareness and mood. Explicit processing, memory encoding, visual spatial analysis, skeletomotor, motivational and attentionl control are the functions of the archicortical limbic division (hippocampus, posterior parahippocampus, retrosplenium, posterior cingulate, supracallosal cingulate). Psychiatric disorders may be reinterpreted within a brain-based framework of limbic dysfunction and divided into three general groups: decreased, increased and distorted limbic syndromes.

FUNCTIONAL LOCALIZATION IN THE CEREBRAL CORTEX

A. Representation of movement

The classical motor area occupies the precentral gyrus, areas 4 and 6, with some spillover into the postcentral gyrus. Stimulation causes a discrete, upside-down somatotopic activation of contralateral muscles through the pyramidal system.

The supplementary motor area occupies the medial hemispheric wall, in area just anterior to the lumbosacral representation in area 4 of the classic motor area. Stimulation of the supplementary motor area produces postural movements, which are more complex (and bilateral) than the disrete movements resulting from stimulation of the classic motor area. PET studies suggests that it may be involved in motor planning, motor imaginary.

The frontal eye field is in the posterior part of the middle frontal gyrus, approximately the inferior part of area 8. Stimulation causes contralateral conjugate deviation of the eyes. Destruction results in ipsilateral conjugate deviation of both eyes.

Apraxia. Apraxia is the inability to execute a normal volitional act, even though the motor system and mental status are relatively intact and the person is not paralyzed. The lesions affect cerebral areas around or distant from the primary motor area but do not involve it. The apraxias differ from the well-categorized lower motor neuron, pyramidal, cerebellar and basal ganglia syndromes. The patient behaves as if the motor engrams or templates for movement have been lost.

Speech apraxia. An area in the posterior end of the inferior frontal gyrus, approximately area 44, close to the primary motor cortex, control the bulbar muscles to produce speech. After its destruction on the left side, the patient loses the ability to utter words, but the bulbar muscles are not paralyzed for other voluntary actions, such as biting, if the primary motor area is spared.

Writing apraxia (dysgraphia). Lesion of the left angular gyrus region may cause dysgraphia. The -patient loses the ability to form letters, although the arm is not paralyzed.

In dressing apraxia the patient cannot orient the clothes to place them on the body. Dressing apraxia usually results from a lesion in the posterior part of the right parietal lobe.

In gait apraxia, the patient becomes unable to stand and walk, although he is not paralyzed. Gait apraxia is usually associated with diffuse cerebral disease.

It is of interest that in both agraphia and acalculia, the motor defect appears to be marred by agnostic defects, hence the common term apractognosia.

B. Representation of primary sensation

The primary somatosensory area (3,1,2) has a somatotopy closely resembling that of the classic motor area. A secondary sensory area is located on the superior lip of the sylvian fissure, adjacent to the insula. Both sensory areas receives relays from the VP of the thalamus, but as with the classic and supplementary motor cortices, the secondary sensory area has a less discrete somatotopy. No special syndrome related to destruction of the secondary sensory area is known in man.

The primary visual receptive area (area 17) occupies the superior and inferior banks of the calcarine sulcus. It has a strict retinotopic representation of the macula and contralateral visual field.

The primary auditory receptive area (areas 41, 42) occupies Heschl's gyrus on the posterior-superior aspect of the superior temporal gyrus in the floor of the sylvian fissure (in front of the planum temporale). The gyri have a strict tonotopic representation. Destruction of one auditory area reduces hearing bilaterally, with somewhat more severe loss contralaterally. Unilateral lesions do not cause complete contralateral deafness because of the bilateral conenctions through the lateral lemniscus.

C. Sensory association areas

The primary cortical sensory areas receive their thalamocortical afferents from the sensory relay nuclei. The association areas receive their thalamocortical afferents from the association nuclei of the thalamus. The primary sensory areas connect with their association areas by means of horizontal fibres in the laminae of the cortex and arcuate fibres. The more generalized meanings may come from (i) numerous progressive arcuate cascades which extend the associations like Huygens wave front; (ii) long association fibers; (iii) callosal connections. The primary sensory areas have few commissural connections through the corpus callosum. These areas are for discrete, topographic representations. The association areas have rich callosal connections in keeping with their role to disperse their information to form widest associations of the primary sensory data.

The primary sensory receptive areas represent their modalities in a strict, keyboard topography. The cerebrum must still interpret the symbolic significance or overall meaning of the sensory stimuli. The cortex surrounding the primary areas represents the sensory data to integrate, analyze, or associate it with the memories, current perceptions, and future goals of the individual.

Destruction of primary sensory areas or the pathways leading to them through receptors, nerves, the spinal cord, lemnisci, the thalamus, or thalamic peduncles causes defects that match the topography and modality of the pathway. The patient suffers numbness, hypesthesia or anesthesia, blindness, or deafness. Irritative lesions of the respective sensory pathways or their primary sensory cortex cause tingling or paraesthesias, flashes of light, or ringing, buzzing sounds. Destructive lesions of association cortex rob the individual of the meaning or symbolic significance of the primary sensation. Such defects of perception are called <u>agnosias</u>. Agnosias are quite different from the <u>neglect</u> syndromes. In neglect, affected individuals deny awareness of sensory information in the affected field, even though sensation remains intact (an individual with contralateral neglect syndrome responds when his left arm is pinched, even though he may deny the arm's existence). Patients with agnosia acknowledge the presence of a stimulus, but are unable to repor exactly what it is. Agnosias can have both a lexical aspect –a mismatching of verbal or cognitive symbols with sensory stimuli – and a mnemonic aspect – a failure to recall stimuli when confronted with them again.

The <u>visual association cortex</u>, approximately areas 18 and 19, gives meaning to visual stimuli, either words or objects. A car speeding toward a person is a pattern of dots on area 17. Areas 18 and 19 represent the car's configuration and associate it with data from the rest of the brain. Thus, the brain recognizes the car, perceives its direction and velocity, and interprets it as a threat to survival.

The <u>somatosensory association area</u>, approximately area 7, is the strip of the cortex behind the postcentral sulcus. It gives meaning or recognition to impulses from the skin afferents and proprioceptors.

The <u>auditory association area,</u> approximately area 22, gives meaning to sounds and, more importantly to spoken words.

D. Agnosias

Agnosia is the inability to recognize the symbolic significance or meaning of a sensory stimulus, even though the sensory pathway and primary sensory cortex are sufficiently intact to register the stimulus and the mental status is relatively intact.

Somatosensory agnosias due to lesions of the parietal association area. Astereognosis ('a' means not; stereo means form; gnosis means knowing) is the inability to recognize the form of an object placed in the hand. For example, a patient cannot distinguish a paper clip from a safety pin by feeling the object. Astatognosia (stat means station) is the inability to recognize the position of the body parts. The greater part of the parietal lobe functions as a center for integrating somatosensory with visual and auditory information, for the purpose of constructing an awareness of the body (body schema=somatognosia; asomotognosia: loss of the body schema) and of its relation to extrapersonal space.

Visual agnosias due to lesions of the occipital lobe lesions. Prosopagnosia is the inability to recognize faces (face blindness) in the presence of intact visual pathways and primary visual cortex. They may also be unable to interpret the meaning of facial expression or to judge the ages or distinguish the genders of faces. In identifying persons, the patient depends on other data. As a rule, other agnosia are present in such cases (color agnosia, simulatagnosia) and there may be topographical disorinetation, disturbances of body scheme, and constructional or dressing apraxias. Visaul field defects are nearly always present, and a left upper quadrantanopia being the most frequent. Prosopagnosia is associated with bilateral lesions of the ventromesial occipitotemporal regions.

Dyslexia is the inability to recognize written words or the meaning of words (word blindness) in the presence of intact visual pathways and primary visual cortex. The lesion responsible for word agnosia is in the association cortex of the left occipital lobe on facies lateralis. Failure to name the object is a rare phenomenon and is usually associated with visual verbal agnosia (alexia) and homonym hemianopia. Prosopagnosia is also present in most cases. The underlying lesion are usually bilateral.

Color agnosia. Color blindness, acquired color blindness (acromatopsia) The disturbance is one of hue discrimination (perceptual disturbance) together with prosopagnosia point to involvement of the inferomesial occipital and temporal lobes and the lower part of the striate cortex or optic radiation. A second group of patients with color agnosia have no difficulty with color perception (they can match seen colors) but they cannot reliably name seen colors or point out color to their names. One form is typically associated with pure word blindness, alexia without agraphia and is best explained by a disconnection of the primary visual area from the language area. The second variety the patient fails not only in tasks that require the matching of a seen color with its spoken name but in purely verbal tasks pertaining to color naming (aphasia restricted to colors). According to Damasio, the lesion has invariably involved the mesial part of the left hemisphere at the junction of the occipital and temporal lobes, just below the splenium. All the patients have a right homonymous hemianopia becuase of the destruction of the left LGB, optic radiation or calcarine cortex.

Visual anosognosia. (noso means disease). The main characteristic is denial of blindness in patients who obviously cannot see. The lesions in cases of negation of blindness extend beyond the striate cortex to involve the visual association cortex.

Cortical blindness. (pupillary light reflex is preserved). Visual imagination and visual imagery in dreams are preserved. Recovery: a regular progression from cortical blindness through visual agnosia and partially impaired perceptual function. The usual cause of cortical blindness is occlusion of the posterior cerebral arteries (embolic or trombotic). The infarct may also involve the medial temporal regions and thalami with resultant Korsakoff amnestic deficits.

Visual illusions (metamorphopsias). Dreamy state, deformation of the image, change in size (macropsia, micropsia), illusion of movement, loss of color, loss of stereoscopic vision, etc. Illusions of this types have been reported with lesions of the occipital, occipitotemporal, occipitoparietal regions and the right hemisphere apperars to be involved more often. Faulty integration of sensory information due to parietal lesions may explain some of the failures to synthesize ocular movement and vestibular function.

The auditory agnosia for spoken words (word deafness) resulting from lesion of the auditory association area (area 22) of the temporal lobe compares with dyslexia (word blindness).

Anatomic studies have established that disturbances of recognition of complex forms, human faces, and spatial arrangements accompany right parieto-occipital lesions. Disturbances of perception of graphic symbols of objects of color discrimination and naming - in short all of the lexical aspects of

recognition are virtually always associated with left parietal-occipital lesions. Agnosias as a higher order perceptual disturbance that can be separated from loss of elementary sensations. Although careful testing of patients with visual agnosia always brings to light some degree of diminished vision in combination with general defect such as confusion and mental disorientation. Geschwind and Sperry empasizes that the visual agnosias depend upon disconnection of the visual receptive zones of the brain and the language areas of the left hemishphre, the learning and memory zones of the temporal lobes, the suprasensory zones of the parietal lobes and the motor regions. Sensations-activation of visual memories (heteromodal association areas)-proper scanning and exploring by the sense organs (sensory-motor integration). Lesion of the right posterior cerebral regions result in an inability to utilize information about special relationship in making perceptual judgement and in responding to object in spatial framework (Constructional apraxia, topographic agnosia, prosopagnosia, simultanagnosia). Also there are claims that the right hemisphere is more important than the left in visual imaginary, attention, emotion and in manual drawing (but not in writing) .

E. Clinical syndromes of agnosias

Anton-Babinsky Syndrome. Left-sided hemineglect: a right posterior parasylvian area syndrome. Symptoms: (i) lacks awareness of the left half of space -he or she ignores tactile, auditory and visual stimuly from the left side and even ignores food on the left half of the palate; (ii) is unable to draw the left half of figures or designs and is unable to reproduce match-stick constructions (constructional apraxia); (iii) is unable to orient clothes for dressing (dressing apraxia); (iv) often does not appreciate the existence of neurologic defects, even when the lesion extends to the paracentral area, causing hemiplegia and hemianesthesia. Failure to recognize such defects is called anosognosia. The lesion responsible for the various forms of unilateral asomatognosia lies in the cortex and white matter of the superior parietal lobule but may extend variably into the postcentral gyrus, frontal motor cortex and temporal and occipital lobes, accounting for some of the associated abnormalities. Rarely, a deep lesion of the ventrolateral thalamus and juxtaposed white matter of the parietal lobe will produce contralateral neglect. Unilateral asomatognosia is seven times as frequent with right parietal lesions as with left sided ones.

Gerstmann Syndrome. Bilateral asomatognosia is due to a left parietal lesion (left angular and supramarginal lesion). The characteristic features are inability to designate or name the different fingers (digital agnosia), confusion of the right-left side of the body (right-left disorienatation) and inability to calculate (dyscalculia or acalculia) and to write (agraphia). One or more of these manifestations may be associated with word blindness and homonymous hemianopia or a lower quadrantanopia, of which the patient is usually unaware. In reaching for a visually presented target in the contralateral visual field and to a lesser extent in the ipsilateral field, the movement is misdirected and dysmetric (the distance to the target is misjudged). This disorder of movement, sometimes referred to as optic ataxia, resembles cerebellar ataxia. This is explained by the fact that cortical areas 7 and 5 receive visual projections from the peristriate areas and proprioceptive ones from the cerebellum. Areas 5 and 7 in turn project to frontal areas 6, 8 and 9 where ocular scanning and rewaching are coordinated.

Balint Syndrome. Symptoms: (i) inability to look voluntarily into and to scan the peripheral field (psychic paralysis of fixation of gaze: the patient is unable to follow a moving object into all four quadrants of the field once the eyes are fixed on it); (ii) failure to precisely grasp or touch an object under visual guidance as though hand and eye were not coordinated (optic ataxia; to reach objects the patient use somatosenory cues. In contrast, movements of the body itself that do not require visual guidance, are performed naturally); (iii) visual inattention affect in mainly the periphery of visual field, attention to other sensory stimuli are intact. The essential feature of the Balint syndrome appears to be a failure to properly direct oculomotor function in the exploration of space. Thus it is closely related to simultanagnosia and to disorder of spatial summation. In all reported cases of Balint syndrome, the lesions have been bilateral, often in the border zones (areas 19, 17) of the parieto-occipital regions.

Consciousness of self and depersonalization. There are many circumstances in which the patient's appreciation of self in relation to the environment is disturbed due to sensory deficit (diplopia, labyrinthine vertigo). These are readily understandable, since in these disorders conflicting data about the external world are presented to the sensorium. Rather, some disorders occurs in the state of continuous self-consciousness, which depends on the influx of sensations and their

association with past memories, the stream of life experiences and feelings that keep us continuously aware of ourselves. Patients with depression of mood may say that they do not feel natural as they move about; it is as though they were frozen in their reactions. The schizophrenic may feel unreal or depersonalized. In a manic attack, every experience may be more vivid, enjoyable and personalized than ever before. Also, delusions of transformation, of being someone else occur in schizophrenia, manic states and general paresis. It is tempting to speculate all these elusive clinical phenomena as manifestations of more general disturbances of the body-environmental scheme.

F. Representation of the language: the aphasias. Calculation

We express language or we receive it. We express it through speaking or writing or receive it through auditing or reading. Thus, we speak/listen or write/read. Disorders in expressing or receiving words as symbols for communication are called aphasias. Aphasia is the inability to understand or express words as symbols for communication, even though the primary sensory systems, motor mechansims or phonation, and mental state (sensorium) are relatively intact.

In most individuals, the critical region for receiving and expressing language is the left parasylvian area and its connections with itself by means of arcuate fasciculi and with the left thalamus through the thalamic peduncles. Anatomically, the left sylvian fissure is somewhat longer than the right, and the supratemporal plane is larger. A prominent arcuate fasciculus runs around the posterior ramus of the sylvian fissure into the posterior inferior frontal region, conencting centers for receptive and expressive speech. Lesions of the left thalamus, which conencts with the parasylvian area, give rise to syndromes of aphasia similar to those resulting from lesions of the cortex or intervening white matter of the thalamic peduncles. Speech is also represented to some extent in the left supplementary motor area, since its destruction may cause aphasia.

The types of expressive and receptive aphasia correlate fairly well with the location of the lesiion within the aphasic zone (Fig. and Table). Lesion site 1 of Fig. cause mainly nonfluent (the patient produces few words), expressive or Broca aphasia with relative preservation of receptive language. Lesions in sites 2-4 in Fig. tend to impair language reception. The patient produces many words and speech sounds, but they are garbled and incomprehensible, so called Wernicke's fluent aphasia.

The recognition and utilization of numbers, arithmetic principles, and calculation, which have important spatial attributes are integrated principially through the dominant parietal lobe. Speech involves cross-modal connections. It is hardly surprising that verbally mediated or verbally associated spatial functions are more affected with left sided than with right sided lesions. Hence cross modal matching tasks are most clearly impaired with dominant hemisphere lesions. Similarly, faults logico-grammatical and syntactic aspects of language occur with left parietal lesions. Such patients can read and understand spoken words but cannot grasp the meaning of a sentence if it contains elements of relationship. In calculation, there are similar effects; the patient may be able to read numbers and describe the rules of a required computation but not be able to carry it out with pencil and paper. In should be noted that addition, subtraction, multiplication and division all require the placing of numbers in specific spatial relationship. The recognition and naming of parts of the body and the distinction of right from left and up and down are other learned, verbally mediated spatial concepts which are disturbed by lesions in the dominant parietal lobe.

SUMMARY OF FUNCTIONS AND DISEASES OF THE INDIVIDUAL LOBES

<u>Parietal Lobe and Parietal Association Areas (areas 5 and 7).</u> These areas process and integrate somatosensory and visual information. From these areas, signals are conveyed to premolor and motor areas. Experiments with single-cell recording in monkeys and lesions in humans indicate that this area is essential for the proper use of somatosensory and visual information, for goal directed voluntary movements and for the manipulations of objects. In humans, the understanding of the meaning of sensory stimuli is seriously impaired (but usually not the mere recognition of a stimulus). This is called the <u>agnosia</u> (depending on the sensory quality concerned we use the terms such as visual, tactile etc agnosia) . The patient is also unable to use well-known tools and objects. This symptom is called <u>apraxia</u>. They furthermore have problems with visually guided movements (such as streching out the arm to obtain an object). Similar symptoms may occur also after lesions of other parts of the hemisphere, for example apraxia caused by a frontal lobe lesion.

The posterior parietal cortical areas also have ample reciproc connections with the cingulate and the prefrontal cortex. These connections are assumed to mediate the influence of emotions, attention, and motivation on behavior produced by somatosensory and visual stimuli.

Unilateral lesions of the <u>right</u> parietal lobe typically produce negligence of the opposite body half and visual space (<u>contralateral neglect</u>, Anton-Babinsky syndrome). The unequal distribution of this particular cognitive function between the hemispheres is thought to arise because the right parietal cortex mediates attention to both left and right halves of the body and extrapersonal space, whereas the left hemisphere only 'attends to the right. Thus, left parietal lesions tend to be compensated by the intact right hemisphere. Imaging studies with PET scanning during specific attention tasks perfromed by normal subjects support this view. Electrophysiological recordings in behaving monkeys confirmed that parietal neurons in area 7 respond selectively when a monkey attends to a relevant stimulus, whether present or remembered.

Another peculiar constellation of symptoms, the Gerstman syndrome, can occur after lesion of the <u>left</u> parietal lobe at the transition to the temporal lobe. The symptoms are as follows: finger agnosia, agraphia, alexia, right-left confusion, dyscalculia.

The ability to integrate somatosensory and visual information and to use visual information to guide voluntary movements is not inborn but learned in infancy and early childhood.

1.<u>Effects of unilateral disease of the parietal lobe, right or left</u>
    A.Cortical sensory syndrome and sensory extinction
    B.Mild hemiparesis
    C.Homonymous hemianopia
2.<u>Effects of unilateral disease of the dominant parietal lobe</u>
    A.Disorders of language (especially alexia)
    B.Gerstmann syndrome
    C.Tactile agnosia (bimanual astereognosis)
    D.Bilateral ideomotor and ideational apraxia
3.<u>Effects of unilateral disease of the nondominant (right) parietal lobe</u>
    A.Visual-spatial disorders
    B.Topographic memory loss
    C.Anosognosia and dressing apraxia.
4..<u>Effects of bilateral disease of the parietal lobe</u>
    Visual spatial imperception, optic ataxia, spatial disorientation, and   severe form of constructional
    apraxia

Temporal Lobe and The Temporal Association Cortex.

Apart from the auditory cortex (areas 41,42, the olfacory cortex in the uncus) and the phylogenetically old parts at the medial aspect, the temporal lobe consists largely of areas 20, 21 and 22 which could be considered as association areas.

The cortex of the superior temporal gyrus is characterized by its connections with the auditory cortex, whereas the inferior parts of the temporal lobe, the inferotemporal cortex are dominated by processed visual information from the exrrastriate visual areas (categorization of complex visual stimuli). In addition, there are strong connections with limbic structures such as the hippocampus and amygdala. Finally, long association fibers interconnect the temporal association area with the prefrontal cortex.

Stimulation of the insula, produces mostly chewing movements, respiratory pattern, abdominal sensations, altered peristaltic movements of the gut, and other vegetative phenomena.

Bilateral damage of the temporal lobes produces pronounced amnesia, which can be ascribed largely to destruction of the hippocampal region Meyer's loop lesion: ventral fibers in the optic radiation, which are related to the lower part of the retina, make a detour into the temporal lobe before proceeding to the visual cortex. A temporal lobe lesion that interrupts this loop produces a contralateral upper homonymous visual defect.

One of the most intriguing agnosias following damage to the temporal association cortex in humans is the inability to recognize and identify faces. This disorder, called prosopagnosia was recognized by neurologists in the late XIX. Century. After damage to the temporal lobe, which can be unilateral or bilateral, such patients are unable to identify familiar individuals by their facial characteristics, and in some cases cannot recognize a face at all. Nonetheless, these individuals are perfectly aware that some sort of visual stimulus is present and can describe particular aspect of it.

L.H. sustained a severe head injury as the result of an automobile accident when he was 18. After his initial recovery, L.H. could not recognize familiar faces, He was nonetheless able to conduct a fairly normal and productive life. He could identify other common objects, could discriminate subtle shape differences, and could recognize the sex, age and likability of faces. Moreover, he coulld recognize particular people by a number of nonfacial cues such as voice, body shape, and gait. The only other category of visual stimuli he had trouble recognizing was animals and their expressions. L.H.'s prosopagnosia derived from a large lesion of the right temporal lobe.

Prosopagnosia is a specific instance of a broad range of functional deficits that have as their hallmark the inability to recognize a complex stimulus as familiar, and to identify and name that stimulus as a menaingful object in the environment. Depending upon the location and size of the lesion, agnosias can be specific as is that for human faces, or as general as an inability to name most familiar objects. These deficits are also distinct from those that arise after damage to the specific regions of the temporal lobe that are crucial for the lexical aspect of the language.

In accord with human recognition deficits following temporal lobe lesions, neurons with responses that correlate with the recognition of specific stimuli are found in the temporal cortex of rhesus monkeys. The behavior of these neurons in the vicinity of the inferior temporal gyrus is generally consistent with one of the major functions ascribed to the temporal cortex, namely recognition and identification of complex stimuli. For example, some neurons in the inferior temporal gyrus respond specifically to the presentation of a monkey face. So far, no face cells have been found that are selective for a particular face; rather they respond to anentire class of faces. In principial, it is unlikely that there are cells that are tuned to specifc faces or objects in an animal's environment (the infamous 'grandmother' cell hypothesis). However, a population of cells, each differentially responsive to various categories of objects, coul dact in concert to enable the recognition of such complex stimuli.

Temporal lobe syndromes include the following

1.Effects of unilateral disease of the dominant temporal lobe
        A.Homonymous upper quadrantanopia
        B.Wernicke's aphasia
        C.Amusia (some types)
        D.Impairment in tests of verbal material presented through the auditory sense
        E.Dysnomia or amnestic aphasia
2..Effects of unilateral disease of nondominant temporal lobe
        A.Homonymous upper quadrantanopia
        B.Inability to judge spatial relationships in some cases
        C.Impairment in test of visually presented nonverbal material
        D.Agnosia for sounds and some qualities of music
3.Effects of disease of either temporal lobe
        A.Auditory, visual, olfactory, and gustatory hallucinations
        B.Dreamy states with uncinate seizures
        C.Emotional and behavioral changes
4.Effects of bilateral disease
        A.Amnestic defect (hippocampal formation)
        B.Apathy and placidity
        C.Increased sexual activity
        D."Sham rage"

The Frontal Lobe and Frontal Association Areas.

Largely correspond to the prefrontal cortex. It receives strong connections from areas in the occipital, parietal and temporal lobes and in addition, from the cingulate gyrus. Thalamic afferents come from the MD. Together, the prefrontal cortex appears to receive information about all sensory modalities and also about the motivational and emotional state of the individual. The prefrontal cortex sends fibers back to most of the areas from which it receives afferents, among them SMA, and PMA. In addition, many prefrontal efferents reach the caudate nucleus and hypothalamus.

Lesions of the prefrontal cortex usually leads to changes of mood and personality, apathy, indifference and emotional leveling-off. The ability to alter the behavior on the basis of experience from previous actions appears to be reduced (perseveration). They also have difficulties in extracting the salient features from a complex situation, making their responses unpredictable and often inadequate. This leads to poor social adaptation, with isolation as the final result.

Neurons that appear to be specifically involved in planning have been identified in the frontal cortices of rhesus monkeys. Monkeys with lesion of the dorsolateral prefrontal cortex cannot form and retain an inner conception of the existence of an object in time and space when the object is no longer seen (lack of the so called underlined delayed response). Delay-specific, or planning neurons in the prefrontal cortex are also active in monkeys that have been trained to perform a variant of the delayed response task in which the response is to internally generated memories.

Clinical effects of frontal lobe lesions

These can be grouped under the following headings: (i) motor abnormalities; (ii) impairment of cognitive function, especially attention, concentration, and capacity for sustained action; (iii) akinesia and lack of initiative and spontaneity (apathy and abulia); (iv)other changes in personality, particularly in mood and self-control (disinhibition of behavior).

1.Effects of unilateral frontal disease, either left or right
    A.Contralateral spastic hemiplegia
    B.Slight elevation of mood, increased talkativness, tendency to joke, lack of tact, difficulty in
     adaptation, loss of initiative
    C.If entirely prefrontal, no hemiplegia; grasp and suck reflexes may be released
    D.Anosmia with involvement of orbital parts
2.Effects of right frontal disease
    A. Left hemiplegia
    B.Changes as in 1B, C and D
3..Effects of left frontal disease
    A.Right hemiplegia
    B.Motor speech disorder with agraphia, with or without apraxia of the lips   and tongue
    C.Loss of verbal associative fluency; perseveration
    D.Sympathetic apraxia of left hand
    E.Changes as in 1B, C and D
4..Effects of bifrontal lesions
    A.Bilateral hemiplegia
    B.spastic bulbar (pseudobulbar) palsy
    C.If prefrontal, abulia or akinetic mutism, lack of ability to sustain attention and solve complex
     problems, rigidity of thinking, bland affect and labile mood, and varying combinations of
     grasping, sucking, decomposition of gait, and sphincteric incontinence.

Occipital Lobe

1.Effects of unilateral disease, either right or left
    A.Contralateral (congruent) homonymous hemianopia, which may be central (splitting the
     macula) or peripheral; also homonym hemiachromatopsia
    B.Irritative lesions -elementary (unformed hallucinations)
2.Effects of left occipital disease
    A. Right homonymous hemianopia
    B.If deep white matter or splenium of corpus callosum is involved, alexia and color naming
     defect
    C. Object agnosia
3.Effects of right occipital disease
    A.Left homonymous hemianopia
    B.With more extensive lesions, visual illusions (metamorphopsias) and hallucinations; more
     frequently with right-sided than left-sided lesions
    C.Loss of topographic memory and visual orientation
4.Bilateral occipital disease
    A.Cortical blindness (pupils reactive)
    B.Anton's syndrome
    C.Loss of perception of color

D.Prosopagnosia, simultanagnosia
E.Balint syndrome

CONNECTIONS OF THE CEREBRAL CORTEX

Cortical afferents.

The cortical layers differ with regard to the origin of their extrinsic afferents. Schematically, pathways conveying precise sensory information end primarily in LIV. This concerns thalamocortical fibers from the somatosensory relay nuclei (VPL, LGB, MGB). Association fibers from the cortex end preferentially in LII-IV. Subcortical afferents with modulatory effects end in severeral layers. Such fibers arise in the intralaminar thalamic nuclei, in the amygdala, hypothalamus, and in the monoaminergic cell groups of the brain stem (dopamine, noradrenaline, serotonin) and the cholinergic neurons in the basal forebrain.

Thalamocortical connections: 1)From specific thalamic nuclei end in precise topographical order. 2)From the intralaminar nuclei, the projections are more widespread and diffuse. Physiological studies indicate that the inlralaminar nuclei exert general effects on the excitability of cortical neurons.

Extrathalamic Corticopetal Afferents. These group of afferents project to large parts of the cortex. Nevertheless they show laminar or areal pattern and terminate with conventional synapses.

Cortical efferents

Depending on their destinations, cortical efferent axons are classed as association, commissural or projection fibers. Association fibers. The axons of cortical neurons, which synapse on ipsilateral cortical neurons, associate these neurons functionally, hence the name association fibers. Commissural fibers: cortical axons that cross the midline to synapse on contralateral cortical neurons. Commissures differ from decussations because commissural fibers cross the midline to connect mirror-image points, wheras decussating fibers cross to contact non-mirror-imaged points. Cortical axons, which synapse on infracortical neurons, "project" the cortical influence onto lower centers, hence, they are called projection fibers. Projection fibers may end ipsilaterally or contralaterally. In the latter case, they are decussations. The term projection axon may also apply to intracortical connections. Any given axon may branch to provide a fiber to association, commissural or prrojection pathways.

1. Association pathways of the cerebral white matter

i. Short association fibers: (i). many association axons synapse close to their neuron of origin. They remain intracortical and do not enter the deep white matter; (ii) association axons, which travel for short distances around the depth of a sulcus, form a visible U-shaped lamina on the undersurface of the cortex, called the arcuate bundle; (iii) the uncinate fasciculus is one of the largest arcuate bundles. In the cerebral white matter, the short fibers, the arcuate bundle, laminate on the inner surface of the cortex, and the long fibres laminae deeper in the white amtter. In the spinal cord, in contrast, the short axons laminate on the outer surface of the gray matter and the long fibers laminate on the periphery of the ground bundles.

ii.Long association fibers. The long association fibers accumulate into more or less distinctive bundles that stand out on gross disection. The bundles continually pay out and receiv axons along their course. In fact, recent studies confirm that a series of arcuate cascades, rather than a single inferior longitudinal fasciculus, connects the temporal and occipital regions. In addition to the longitudinally running long bundles, pathways of intermediate length crisscross vertically and transversely between facies medialis and facies lateralis or in a superior to inferior direction in all of the lobes. Lesions of the long pathways disconnect one part of the cerebrum from another and from infracortical centers, leading to varying degrees of motor and sensory deficits and dementia. Certain demyelinating diseases preferentially attack the long pathways, sparing the arcuate bundles.

iii.Cingulum.. The cingulum is the long and short association pathway of the limbic lobe. It girdles the hemisphere from the parolfactory and subcallosal regions of the frontal lobe around to the parahippocampla gyrus and temporal pole. A limbic component of the uncinate fasciculus then completes the limbic ring by connecting the temporal lobe to the inferior frontal region. The temporal cortex that receives the limbic connections of the cingulum and uncinate fasciculus sends axons to the hippocampus as the temporoammonic tract of Cajal and the temporoalvear tract as part of the Papez circuit. In addition to its cortical connections, the cingulum distributes axons from the limbic nuclei of the thalamus and to the corpus striatum. Cingulotomy by stereotaxic surgery may reduce the reaction of the chronically ill patient to pain and may reduce the intensity of obsessive-compulsive neuroses.

2. Cortical commisssures

i.Corpus callosum. Through its middle lamina, the corpus callosum conenects mirror-image areas of the cortex of the two hemispheres. Its dorsal and ventral lamina convey axons of the cingulum. Those axons that curve around the interhemispheric fissure anteriorly comprise the forceps minor; they form the genu. Those curving around posteriorly comprise the forceps major; they form the splenium. Some regions lack transcallosal conenctions, including primary sensory areas 1,2, and 17 and part of the auditory receptive area (area 41) and those parts of the motor cortex (area 4) serving the upper and lower extremities. In contrast, the motor areas for the face, shoulder, and pelvic girdle and trunk do have callosal connections. Anterior superior frontal region also lack transcallosal conenctions.

ii.Hippocampal commissure. The hippocampal commissure connects the hippocampal formations of the two hemispheres. Moved backward by the growth of the corpus callosum and the migration of the hippocampla formations, the hippocampal commissure crosses benetah the posterior part of the body of the corpus callosum.

iii.Anterior commisssure. The anterior commissure crosses in the commisural plate ventral to the corpus callosum. Phylogenetically, it originates as a noncortical or rhinencephalic commissure, linking the olfactory bulbs, the amygdala and other basal forebrain neurons. In higher animals, neocortical fibers linking the frontal and temporal cortex predominate. The fibers laminate in the same manner as the corpus callosum.

Clinical effects of cerebral commissurotomy: Sagittal section of the corpus callosum, anterior commissure, and optic chiasm disconencts the two cerebral hemispheres. The individual has a split brain and cannot transfer infomation from one hemisphere to the other. Specific test are required to demonstrate the deficits. If blindfolded, the individual cannot match an item held in one hand or seen in one visual field with what is felt or seen on the other side. A right handed patient can execute a verbal command with the right hand because the left motor cortex remains conencted to the language centers of

the left hemisphere. The patient cannot execute the command with the left hand because the right hemisphere, disconencted from the left, does not understand language. The fibers of the corpus callosum may fail to cross during development (agenesis of the CC). The fibers then accumulate along the ipsilateral ventricular wall, rather than crossing in the commisural plate.

Cortical Neurons and Intrinsic Circuits

Considering only salient features, we can say that layers 2 and 4 are mainly receiving -being most developed in the primary sensory areas -whereas layers 3 and 5 are mainly efferent and send their axons out of the part of the cortex in which they are located. The pyramidal cells of layer 5 send their axons primarily to subcortical nuclei, and this layer is particularly well developed in Ml. The layer 3 pyramidal cells send their axons primarily to other areas of the cortex (association and commissural fibers). Layer 6 is also largely efferent and sends many axons to the thalamus.

Excitatory and inhibitory connections, <u>impulse traffic</u>. For example, in the visual cortex axons from the LGB first activate cells in LIV. From LIV the excitation is propagated to LII and III, from there to LV and VI. Some cells in LVI send axons to LIV.

Each cortical neuron integrates information from many other neurons. A pyramidal cell in monkey Ml may receive about 60,000 synapses. <u>Cortical columns</u>: A tendency for cortical neurons to be arranged in perpendicular rows is evident from thionine-stained sections. That neurons within such a column share functional properties that differ from those within adjacent columns was first described by Mountcastle (1957) in the monkey SI. The relation between the tendency for cortical neurons to be arranged in columns and the physiologically defined columns, however, is not clear.