The vast panorama of the history of neurologic thought viewed through the ages is an experience by itself. The knowledge of the functions of the nervous system, which in some respects preceded the knowledge of its anatomy, remained obscure for many centuries. Cranial cavity was taken to be an inner sanctum barred to the surgeon's scalpel and was last to be invaded after abdomen and thorax had been conquered. The seat of life, therefore, shifted finally to the contents of the cranium—the basic concept of neurology and Psychiatry to day.

Literature reveals that neurologic affections, meningitis, migraine palsies and tremors were all well known to the ancient Greeks and Egyptians long before Hippocrates was born. The
progress of the understanding of functions of nervous system has, however, remained unsteady and was impeded because of the great conflict between dogmatic traditions and experimental observations. This seems to have resulted "in the historical clash between the two principal attitudes governing neurological thought - the metaphysico-religious, and the empirico-scientific".

Neurology as a scientific speciality made its appearance comparatively late, hardly a century back. In words of Fulton (1951) "among the most significant developments in modern neurology if not in all scientific medicine - has been the gradual recognition of the existence of vast areas in the forebrain subserving autonomic functions and forming the structural background not only of emotional expression, but of affective behaviour in the broadest sense".

Paul Broca shares the laurels of being the famous first to define limbic lobe as early as 1878 when he demonstrated that a large convolution which he called the great limbic lobe, surrounds the brainstem and forms a common denominator in the brains of all mammals. Broca thus remained busy primarily with the gross morphological relations of the limbic lobe. It was for Ramón Cajal (1903) to add another milestone in the history of limbic system who for the first time gave an adequate analysis of the finer structure and connections of this phylogenetically ancient part of the brain. Almost simultaneously hypothalamus was spotted by a number of Austrian workers. It has been aptly said that hypothalamus was "born in Vienna". Through the works of Babinski (1900), Alfred Fröhlich (1901), Karplus and Kreidl (1909 to 1937) to mention a few, and later Ranson and his colleagues (1935, 1938, 1939, and 1940) and Hess (1945, 1947, 1948 and 1949)
and many others, hypothalamus came to be regarded as a central effector organ of the autonomic activities and was designated by Sherrington as the "head ganglion" of the autonomic nervous system. Cajal (1903) was aware that all parts of limbic system were interconnected and that the limbic system as a whole projected to subcortical nuclei including hypothalamus. The word 'limbic system' was thus adopted for the cortex contained in the great limbic lobe of Broca and its associated subcortical cell stations. The importance of this well defined anatomical entity remained neglected till quite recently when it was realised that large cerebral lesions of frontal and temporal lobes influence many phases of autonomic functions as well as patterns of emotional behaviour. Papez (1937) in his brilliant paper entitled "A proposed mechanism of emotion" expressed that the hypothalamus, the anterior thalamic nuclei, the gyrus cinguli, the hippocampus and their interconnections, - the so called rhinencephalic structures (limbic system), constitute a functionally integrated system "which may elaborate the functions of central emotion, as well as participate in emotional expression". This theory of Papez with the additional support of experimental work in the following years seems to set a foot on a firm basis the hypothesis that the limbic system provides a common denominator for a variety of emotional and viscero-somatic reactions in the mammals.

The suggestion that the limbic system represents an early neural development involved in the higher control of autonomic nervous system and affectively determined behaviour (Maclean, 1949) has resulted in assigning such a conspicuous importance to this part of the brain. It seems to integrate the higher intellectual functions of the neocortex with the more primitive visceral
functions. Since 1950 these relations have been notably clarified by many workers (Fulton, 1951, 1953; Kaada, 1951, 1952; Downman, 1951, 1952; Amassian, 1951, 1952; Maclean, 1952, 1954, 1958; Delgado, 1952; Pribram, 1950, Pribram and Kruger, 1954; and Kliver, 1952). As a result of their studies, the limbic lobe has emerged as a distinct functional entity concerned primarily with the regulation of visceral organs and elaboration of affective behaviour, while the neocortex is recognised as presiding in large measure over conscious sensory perception and the more purely intellectual functions of the brain. Maclean (1949) draws the conclusion that limbic system "appears to be so strategically situated as to be able to correlate every form of internal and external perception, and the possibility exists in this region for bringing into association not only oral (small, taste, mouth) and visceral sensations, but also impressions from sex organs, body wall, eye and ear". On the basis of these conclusions MacLean (1949) has designated this region of the brain as "visceral brain".

Before the important evidences, experimental and clinical, of the role of limbic system structures in influencing various autonomic and behavioral activities are reviewed in the following pages, a short summary of the evolutionary importance and anatomical considerations of the limbic system are being described to give a better understanding of its functional significance.

**PHYLOGENY AND LIMBIC SYSTEM**

The design of neural chassis included within the brain-stem and spinal cord seems to be essentially similar in all animals. This neural chassis provides the basic mechanism required for
posture, locomotion, and the integrated performance involved in self preservation and preservation of the species (MacLean, 1958). The analogy of such a chassis to one of an automobile (MacLean 1954) is indeed very apt. It is the development of "a driver at the wheel, to give it direction and to decide on alternative courses of behaviour" that represents in evolution the chief modification.

The change of relatively stable marine life to a more unpredictable terrestrial life during the course of evolution brought in its vogue the problems of wide adjustments for the animal to face. It is presumed that the elaboration of forebrain has kept pace with such a change (Johnston, 1923). Significantly enough, the new formation is organised around the sense of smell, a sense that is unique by being intero- and exteroceptive, and one that is vitally concerned in "feeding, nutrition, reproduction" and avoiding what is harmful (Herrick 1933). MacLean (1954) has beautifully pictured the possible role of the budding driver. "It was as though Nature, in fashioning the new driver, had sought to compromise on one who would ensure homeostasis between the new demands of the outside world and the continued needs of the inside world". Such is the position of limbic system.

Studies on comparative neurology indicate that limbic lobe forms a common denominator in the brains of all animals. This is illustrated in (Fig.1) in which the brains of the rabbit, cat and monkey are drawn roughly to scale and the limbic lobe is represented in black. The faithful reduplication of this "old" cortex throughout the phylogeny of mammals contrasts with the rapid evolution and growth of the neocortex around it.

Three types of cortex referred to as Archi-cortex, mesocortex
Those drawings illustrate that the limbic lobe, represented in black forms a common denominator in the brains of all mammals. The medial and lateral surfaces of the rabbit's (a), cat's (b), and monkey's (c) brain are drawn roughly to scale. Note how the limbic lobe surrounds the brainstem. Limbic means "forming a border of around". (From MacLean 1958).
and neocortex and better visualised as an uninflated balloon with three segments (Fig. 2), represent the situation found in amphibians. With the appearance of reptile, there is a ballooning out of the archicortex - the first cortex to differentiate, and considerable expansion of mesocortex. During the phylogeny of mammals there is the great ballooning of the neocortex. In the process, the archicortex and the greater part of the mesocortex are folded like two concentric rings into the limbic lobe (Fig. 3).

The olfactory apparatus, ancient in origin, forms the basic tubular structure from which other portions of the visceral brain are developed. In fishes and amphibians the olfactory bulbs are formed from the terminal parts of forebrain vesicles. The olfactory bulbs are connected by nerve fibres to the walls of the forebrain vesicles where rudiments of the olfactory and preoptic areas, amygdala (archistriatum), basal ganglia, fascia dentata and hippocampus are developed (Papez, 1958). In lower mammals there is an elaboration of visceral forebrain in all its parts. The visceral cortex, claustrum, amygdala, septum, hippocampal formation and olfactory striatum form prominent features of brains of macrosmatic mammals, collectively called the visceral brain. Development of neopallial cortex is a later event which brought with it connections to the hippocampal gyrus.

Cytoarchitectural studies reveal that cellular elements of archicortex and paleocortex form essentially two layers corresponding functionally to receptive granular layer IV and the efferent pyramidal layer V of the neocortex (Ariens Kappers, 1928); the paleocortex "showing a higher stage of development". Cortex of limbic lobe comprises of the two foregoing primitive types together with the transitional mesopallial cortex developing
The uneven expansion of a toy balloon with three segments illustrates the relative growth of the archicortex (A), mesocortex (M), and neocortex (N) during phylogeny. The stick holding the balloon would correspond to the brainstem. The uninflated balloon represents the situation in the amphibians. The archicortex and greater part of the mesocortex (stipple) become folded into the limbic lobe. (From MacLean 1958).
adjacent to them (Lorente de Nó 1934, 1934*, 1949)* One of the most striking features distinguishing the neocortex is the great elaboration of the so-called supragranular layers in the outer lamina with a number of cells with short axons "an anatomical expression of the delicacy of function of the brain of man" (Cajal, 1903).

Phylo-genetic and cytoarchitectonic studies thus suggest that the limbic lobe, though undergoes some expansion and reaches its greatest development in man, retains essentially its position and structural characteristics throughout the entire mammalian series. The neopallium, on the other hand continues an exuberant growth becoming a massive tucked up sheet in man that folds over and crowds the limbic lobe into the cellar, as it were, of the brain.

ANATOMICAL CONSIDERATIONS OF LIMBIC SYSTEM

1. Components of limbic system.

The limbic system is comprised of the cortex contained in the great limbic lobe of Broca including the infolded hippocampus and its subcortical cell stations. In Papez's terminology (1929) the cortex of the great limbic lobe is contained in the following structures: cortex adjacent to the olfactory striae, pyriform area, hippocampal gyrus and hippocampus, parasprenial, cingulate and sub callosal gyri. The cortex of the insula and temporal polar gyrus that adjoins the rhinal fissure (inferior arc of limbic fissure of Broca) has cytoarchitectural similarities to limbic cortex, but by Broca's definition would be outside the limbic lobe because it is peripheral to the fissure.
Schematic drawings placing emphasis on the medial forebrain bundle (MFB) as a major line of communication between the limbic lobe and the hypothalamus and mid-brain. Note its relation to the fornix and cingulum that become separated through the growth of the corpus callosum. The concentric rings of archicortex and mesocortex are portrayed, respectively, in dark and light stipple. A, ascending pathways to limbic lobe, with emphasis on divergence of fibers from MFB to amygdala and septum. B, descending pathways from limbic lobe. A.T., anterior thalamic nuclei; C.G., central gray of mid-brain; D.B., diagonal band of Broca; G, ventral and dorsal tegmental nucleus of Gudden; HAB., habenula; HYP., hypothalamus; I.P., interpeduncular nucleus; L.M.A., limbic mid-brain area of Nauta; M, mammillary body; PIT, pituitary; S.G., superior geniculate (From MacLean 1938).
The important components of the limbic cortex described are the orbitomedial surface of the frontal lobes, the anterior cingulate gyrus, the anterior insular area, the temporal polar area, the pyriform (periamygdaloid) area, the hippocampal and dentate gyri, and the uncus (Fig. 4). Its subcortical cell stations include the amygdaloid nuclei (further subdivided into antero-medial and basolateral group), the hippocampus (Ammon's horn) (Fig. 5), the septal nuclei, the hypothalamus, the anterior thalamic nuclei, parts of basal ganglion, and perhaps also the epithalamus (Anand 1957).

With the rapidly accumulating evidences about the implication of medial and basal cortex of the cerebral hemispheres in visceral and emotional processes, attempts have been made by various workers to classify the different parts of limbic system in some orderly fashion. In view of the similarity observed both of cytoarchitectural structure and responsiveness to stimulation, of the temporal tip, the insula and the anterior cingulate, the original anatomical components of limbic system had to be classified on a rather functional basis.

2) Afferent and efferent connections.

Kappers et al. (1936), by demonstrating the presence of spino-hypothalamic connections in fish and certain other lower forms, made a very significant contribution. They showed that this ascending system passes to hypothalamus quite independently of the classical spino-thalamic tract. By now enough of evidence has accumulated to show the presence of visceral afferents ascending from spinal cord through medulla and midbrain to hypothalamic and adjacent nuclei in the form of two large extralemniscal systems (Ibanez, 1935; Tello, 1936; Bronk, 1940; Dell, 1952; Downman 1952; Anassian, 1951; and Aider et al., 1952).
Fig. 4

Semidiagrammatic representation of different parts of the limbic system on the medial and ventral surfaces of the cerebral hemispheres. Cortical areas surrounding the hilum constitute the great limbic lobe of Broca.
French et al. (1953) reported that a large part of these extra-lemniscal fibres terminate in the reticular formation and projected from there to various parts of the forebrain including the limbic system.

Bailey and Bremer (1938) observed increase of cortical potentials in orbital surface of frontal cortex on excitation of vagus nerve in cats and thus suggested the possibility of afferents received by this region of the brain from visceral organs.

Hippocampus besides showing train of evoked potentials on stimulation of reticular activating system (Green and Arduini, 1954) has been demonstrated to receive visceral and external (somatic) sensations. It is considered to be an important region for integration of internal and external sensations. MacLean et al. (1952) by showing conspicuous electrical responses in pyriform area in response to noxious stimuli (pricking ear or foot), have put forward the interesting possibility of pain stimuli being transmitted to limbic system.

Recently Anand et al. (1959) have reported the presence of afferents to limbic system from paleo-cerebellar structures. It has been shown that posterior part of paleo-cerebellum and flocculonodular lobe projects to limbic structures of the frontal and temporal lobes and to the hypothalamic regions. The anterior part of the paleo-cerebellum was found to evoke potentials only in the orbital cortex, hippocampus and hypothalamus while neo-cerebellar regions of vermis seem to have no projections to the limbic system except possibly to hypothalamus.

The limbic structures send out efferent impulses to the viscera via autonomic outflow. The more intimate knowledge
Upper figure is semidiagrammatic representation of transverse section through temporal lobe and diencephalon showing the arrangement of amygdaloid nuclei in relation to hypothalamus and thalamus. Lower figure is a transverse section of temporal lobe through hippocampal and dentate gyri, showing the arrangement of hippocampal formation. Abbreviations used are: Med. - Medial nucleus of amygdala, cort. - cortical nucleus of amygdala, Lat. - lateral nucleus of amygdala, Bas. L. and Bas. M. - basal nucleus of amygdala (lateral and medial parts), Pyr. cort - Pyriform cortex, F. Rhin. - rhinal fissure, C.I. - internal capsule, Pall. - globus pallidus, Put. - Putamen, claus. - claustrum, To-optic tract, Hyp. - hypothalamus, III-third ventricle.
of the part played by the forebrain in integration of autonomic functions came with the studies of Karplus and Kreidl (1909, 1910, 1912) who observed striking effects, autonomic in nature, on stimulation of hypothalamus. Through the later studies of Hess, Bard, Bailey, and Brener, and many others, it was concluded that hypothalamus is intimately connected with the autonomic outflow. Hypothalamus was also shown to regulate endoc floral activities of the body by influencing the activity of pituitary gland.

Kaada (1951) showed that following bilateral vagotomy the blood pressure falls obtained by stimulation of the anterior limbic, orbitoinsular, pyriform and temporal cortex was greatly reduced or abolished. Bilateral vagotomy was also shown to abolish both inhibitory and augmentary responses of anterol motility obtained by stimulation of area 13 and adjoining deeper areas extending into anterior insular region, rostral end of hippocampal gyrus and temporal polar cortex (Kaada, 1951). These are highly suggestive of the descending impulses from these cortical areas being mediated through vagi.

The mechanism of pupillo-dilatation from the medial precallosal field was found to involve sympathetic excitation as well as parasympathetic inhibition (Siebens and Woolsey, 1946). Amygdala was shown to project to midbrain tegmentum - reticular formation (Gloor, 1954). Thus the recent experimental studies on regulation of visceral activities and affective behaviour tend to show that limbic system structures do have efferent connections with the autonomic and endocrine systems. These might be operating through the
connections of these regions with the hypothalamus; or some of these regions may be sending direct efferents to the reticular formation.

3. Interconnections.

Specific response from a particular region of the limbic system cannot be made to explain the wide variety of clinical manifestations that may be met with in the affections of these areas. Recent physiological and anatomical studies indicate that such a picture is the sum total of activities of a great many anatomical and functional subdivisions of limbic system which are intimately interconnected.

The complex limbic system is mainly fed on its afferent side by the mammillary peduncle, median forebrain bundle and the olfactory bulb. Most of the ascending impulses of visceral origin after impinging upon hypothalamus (Fulton, 1951) divide into two groups. One group follows the following anatomical circuit (Le Gros Clark and Meyer, 1950):

Mammillary body → anterior thalamic nuclei → cingulate gyrus → cingulum → hippocampus → fornix → mammillary body.

The second group of projection passes to midline and dorsomedial thalamic nuclei. From here they project to posterior orbital, anterior insular and temporal polar regions. These regions are reciprocally connected (Baily et al. 1943; Peter et al., 1949; Lennox et al., 1950; Pribram et al., 1950, MacLean and Pribram, 1953) as well as project into the cingulum and the amygdala, which further are
connected to the rostral hippocampus and hypothalamus.

Pribram and MacLean (1953) and MacLean and Pribram (1953) tried to explore the interconnections between the limbic and extra limbic cortex of the medial and basal aspects of cerebral hemispheres by the method of strychnine neurography. Based on these studies, they have divided these parts into the following five regions (Fig.6).

(i) Fronto-temporal.
(ii) Medial occipitotemporal.
(iii) Medial parieto-occipital.
(iv) Medial fronto-parietal.
and (v) Medial frontal.

They have further shown that in the monkey the posterior orbital, anterior insular, pyriform, temporal polar, entorhinal, parasplenial and posterior cingulate areas fire into the hippocampus. But no reciprocal connections between hippocampus and the other regions were established by them.

Firing by the entire fronto-temporal region as well as the entorhinal area of the medial occipitotemporal regions into the amygdala have also been demonstrated by them. The stria terminalis constitutes one of the principal efferent pathways for certain of the amygdaloid nuclei like corticomedial and establishing connections for these nuclei with septal, preoptic, hypothalamic and epithalamic centres. (Fox 1943; Gurdjian, 1927 and 1928; Humphrey, 1936; Kapper et al., 1936; Smith, 1930; and Young, 1936). Stria terminalis has further been differentiated into different components and their functional importance emphasized by these authors.
Various shadings represent five regions comprising limbic and extra-limbic cortex that can be differentiated by physiological neurography. The fronto-temporal region is shown in stipple. Top two figures show lateral and medial surfaces of cat's brain; bottom two figures are corresponding representations of monkey's brain (From MacLean, 1952).
Responses from basolateral complex of amygdala have indicated the possibility of the existence of an intra-amygdaloid association system with short axons (Crosby, 1954), a postulate supported by anatomical findings of various workers (Fox, 1940, 1943; Hilpert, 1928; Johnston, 1923; Krieg, 1947).

Direct connections from the amygdala to mesencephalic tegmentum (Davis, 1951), amygdalothalamic fibres (Fox, 1949, and Hilpert, 1928), connections from the basolateral amygdaloid complex to pyriform cortex (Crosby and Humphrey, 1944; Gurdjian 1928; Johnston, 1923; and Lauer, 1945), and amygdalo-hippocampal connections (Fukuchi, 1952; Gurdjian, 1928; Hilpert, 1928; Johnston, 1923; Loo, 1931 and Mittelstrass, 1937) have also been reported. This analysis of the neuronal organisation of the amygdaloid projection system reveals a very intimate relationship of the amygdala with highly integrative subcortical structures (Fig. 7).

The medial forebrain bundle and its continuation as the cingulum may be considered to be to the limbic lobe what the internal capsule is to the outer convexity of the brain (MacLean, 1958). It has become evident (Nauta et al., 1956, 1958) that this central grey and paramedian reticulum of the mid brain provides the vital link between the limbic cortex and the lower brain-stem and spinal cord and has been designated by Nauta (quoted by MacLean, 1958) as "limbic mid brain area". The medial forebrain bundle diverges into two large streams of fibres. One turns laterally to the region of the amygdala where it converges with the descending fibres from the lateral olfactory tract. From the amygdala
Diagram of the neuronal organization of the amygdaloid projection system. The dotted area comprises the subcortical integrating structures regulating "global" somato-autonomic and "diffuse" projection mechanisms as well as the rhinencephalic structures projecting into this subcortical system (from Gloor, 1955).
fibres distribute to the limbic cortex of the fronto-temporal region. The other stream runs medially to the septum where it converges with fibres descending from the medial olfactory tract. From here the fibres are distributed by way of the fornix and cingulum respectively to the hippocampus and cingulate gyrus.

The septal region seems to hold a strategic position due to the fact that many fibre tracts converge towards this region in order to enter or leave the telencephalon.

The afferent and efferent connections of hippocampus have been revealed and their importance realised as a result of various anatomical and electrophysiological studies (Nauta, 1956; Blackstad, 1956; Simpson, 1952; Daitz and Powell, 1954; Powell and Cowan, 1954, 1954a; Cowan and Powell, 1954; Gerebšt-zoff, 1941; Morin, 1950; Allen, 1944; Sprague and Meyer, 1950; Guillery, 1956; and Fox 1940, 1943). It is believed to receive afferent fibres from the cortex of the entorhinal area, the cingulate gyrus, the prefrontal neocortex, hypothalamus and brain-stem directly and by way of the septum. As for the efferent side direct connections to the medial mamillary nucleus are well-known. Some fibres from the fornix have been shown to project directly into the tegmentum (Nauta, 1956; and Guillery, 1956). Lateral portions of the hippocampus have been shown to project chiefly to the septum and hypothalamus. The possibility of direct connections between hippocampus and thalamus has also been suggested. Papez (1938) while describing the limbic system under the headings of (i) olfactory (ii) visceral and (iii) hippocampal
systems, emphasized the role of complex hippocampal pathways in emotions.

It would thus appear that the limbic system is intimately interconnected by means of rich projections and reciprocal connections. It seems to behave as a well integrated functional entity rather than a combination of discrete anatomical regions. The various structures of the limbic system are not only interconnected, but they are connected in a cyclic manner (Fig.8).

**EXPERIMENTAL STUDIES**

Clinical observations and experimental evidences kept on reinforcing each others value and helped towards a better understanding of the functional localisation in the limbic system. For the development of such a concept of cerebral localisation, the role of stimulation and ablation techniques hold an important position in the history of neurophysiology. The earlier investigators of nineteenth century were handicapped by the lack of adequate methods at their command. Yet much came to be known about the functions of the cortical areas with the means available at that time. In the latter part of that century ablations of parts of brain were attempted. By that time embedding and staining techniques had also been sufficiently developed to allow the examination of the brain in serial sections, so that the extent of damage to subcortical structures could be accurately assessed. Once it became evident that there was a localisation of function in cerebral hemispheres, physiologists
Fig. 8

Schematic drawing indicating divergence of pathways from brain-stem and olfactory bulb into respective portions of the limbic lobe. DB, diagonal band; L, lateral septal nuclei; M, medial septal nuclei; OLF, olfactory. (From MacLean, 1958).
were enthusiastic to explore the effects of regional ablations on various bodily activities.

The origin of stereotaxic apparatus (Horsley and Clarke, 1908) coupled with the newer electronic devices have unfolded a new chapter in the history of neurophysiology. It has become possible to explore the hidden parts of the brain with much accurate localisation. To keep pace with the rapidly progressing neurosurgical techniques developed for various psychotic and epileptic disorders, it was much realised that the knowledge about the functional representations of different limbic regions was very essential for better understanding of the rationale and the therapeutic results of such procedures.

During the recent few years a host of workers have attempted to study the relationship of different limbic regions to various autonomic and behavioral changes both in anaesthetised and unanaesthetised states. So exhaustively has the problem been tackled, that workers started realising soon, that the study of the entire limbic system was rather too extensive to be undertaken for simultaneous investigations. Attention was, therefore, focussed towards the fronto-temporal region of this system which has been quite extensively explored. Many gaps, however, still remain to be filled before any comprehensive picture can be drawn.

In the following pages a short review of the relationship of limbic system to such activities is being attempted. The various responses have been described under appropriate headings of different systems of the body.
Although one of the primary autonomic foci of the frontal lobes is on the orbital surface, it had been much neglected in the past, as far as experimental studies are concerned, largely because of its inaccessibility. Tumours of this region particularly the olfactory groove meningiomas are relatively common but they are not prone to cause symptoms since they are slow growing and are seldom bilateral (Fulton, 1949). Schiff observed acceleration of heart on faradization of frontal lobe as early as 1875. In a long forgotten paper the London surgeon, W.G. Spencer (1894) reported changes in blood pressure on faradization of the posterior part of orbital surface in dogs, cats, rabbits and monkeys. Spencer's observations were lost sight of for nearly fifty years.

Bailey and Sweet (1940) stimulated a small area on the posterior orbital surface and found changes in blood pressure akin to those described by Spencer. Delgado (1947) reported vasomotor phenomenon without any somatic effect other than that connected with respiration on stimulation of orbital surface.

More studies in animals by Livingston et al. (1947), Delgado and Livingston (1948), Kaada et al. (1949) and Turner (1954) have further confirmed the earlier observations. Rise of blood pressure resulting from stimulation of orbital surface had been a constant finding with all these people. Sachs and Brendler (1948), on the other hand, observed two types of effects, a slow moderate rise or an instantaneous moderate fall on stimulation of orbital
surface. Livingston et al. (1947) and Chapman et al. (1949 and 1950) had the opportunity to study the relationship of blood pressure and respiration to frontal and temporal lobes in patients with psychiatric disorders. In one group of patients observed for one year after frontal lobotomy, no significant effect on blood pressure was observed. It only caused a temporary lowering of systolic blood pressure in psychotic patients who had varying degrees of elevated blood pressure. In another series stimulation of orbital surface in majority of patients under light anaesthesia led to rise of blood pressure. Freeman & Watts (1936) and other lobotomists also observed striking changes in systolic pressure in patients having essential hypertension. Delgado and Livingston (1948) reported sharp vasodilation in the extremities on placing a cold cotton pledget against the orbital surface of frontal lobe.

Smith (1941, 1945) and Ward (1948) established the autonomic affinities of the cingulate gyrus by observing either an abrupt fall of pressure and slowing of pulse or gradual rise with cardiac acceleration depending upon the intensity of stimulation and the particular focus stimulated. The same has been observed in dogs by Kremer (1947) and Speakman and Babkin (1949) on stimulation of anterior limbic region. Pool and Ransohoff (1949) and Pool (1954) made similar observations in man. Lennox and Robinson (1951) did not observe any change in the electrocardiogram on stimulation of the anterior cingulate. Showers (1959) noted that on stimulation of cingulate gyrus in monkey, the heart beat
became alternately very rapid and weak and very slow and strong. The scope of experiments when extended to adjoining temporal regions led to similar responses.

Kaada et al. (1949) observed rise of blood pressure on electrical excitation of temporal pole and uncus in anaesthetised monkeys. Chapman et al. (1950) noticed striking rise in blood pressure on stimulation of temporal tip in one patient under pentothal anaesthesia. Kaada (1951) in his further studies reported fall of blood pressure on stimulation of anterior insular, anterior hippocampal gyrus and neighbouring temporal regions in monkeys and the homologous areas in cats and dogs. Stimulation of points in the amygdaloid and caudate nuclei also led to fall of blood pressure but no significant responses were observed by excitation of hippocampus and fornix. MacLean and Delgado (1953) observed slowing of the heart more commonly from the rostral amygdala and overlying cortex than elsewhere in unrestrained animals. Similar changes from other regions are reported by Kaada (1953). Rise in blood pressure with increase in heart rate on stimulation of amygdaloid nuclear complex was recorded by Koikegami et al. (1953, 1957) in animals and by Chapman et al. (1955) in human beings. Wood et al. (1956) obtained consistent fall of blood pressure on stimulation of amygdaloid complex in deeply anaesthetised rats.

It would thus be apparent that these studies do not lead to any definite conclusions. Differences in species, anaesthesia, techniques and parameters used have tended to give dissimilar results in different hands. A comprehensive
study is, therefore, required to explore the regions systematically and explain the effects produced. The present study is an attempt towards that goal.

2) Respiratory System.

Spencer (1894) was the first to stimulate orbital surface of frontal lobe in a systematic fashion. He observed prompt and complete arrest of respiration in an expiratory position on faradization of posterior part of orbital surface in lightly anaesthetised rabbit, cat, dog and monkey. Interest in the orbital surface of frontal lobe was later revived by Bailey and collaborators. With Bremer in 1938, Bailey found that stimulation of the central end of the vagus nerve increased the electrical potentials of this part of the frontal cortex. In 1940 Bailey and Sweet observed inhibition of respiration on stimulation of orbital surface both in monkeys and cats but more marked in monkeys. These observations were later confirmed by Delgado (1947), Livingston et al. (1947), Delgado et al. (1948), Sachs and Brendler (1948), Kaada et al. (1949) and Turner (1954). In most of these studies it was observed that blood pressure and respiratory responses had different thresholds and each could be obtained independently as well. Livingston et al. (1947) and Chapman et al. (1949) noticed cessation of or decrease in respiration in the expiratory phase on stimulation of orbital surface of frontal lobe in majority of their patients under light pentothal anaesthesia.

Smith (1941 and 1945) and Ward (1948) noted that respiratory inhibition either independently or with
other effects could be obtained on stimulation of the cingulate region in monkey. Lennox and Robinson (1951) observed arrest of respiration during stimulation of the anterior cingulate gyrus in the anaesthetised cats and monkeys. Occasional hyperpnoea is also reported. Respiratory inhibition on stimulation of the anterior limbic cortex has also been obtained in dogs (Bremer 1947; Speakman and Babkin, 1949) and man (Pool and Ransohoff, 1949; Pool, 1954). Hess et al. (1952) suggested that the orbital and cingulate gyri on stimulations give acceleration in unanaesthetised and inhibition in anaesthetised animals. Showers (1959) on the other hand demonstrated respiratory changes occurring with emotional expression of the experimental animal on stimulation of cingulate gyrus. These included increase or decrease in rate, noisy respiration, vocalization and apnoea. Smith (1938) described a separate temporal inhibitory field for cat and dog. Kaada et al. (1949) and Kaada (1951) observed partial or complete inhibition of respiratory movements on electrical stimulation of anterior end of hippocampal gyrus, temporal pole, uncus and anterior insula. The inhibition was mainly of amplitude although the rate of respiration at times also decreased. Stimulation of rostral pyriform cortex also produced such changes (Kaada et al. 1949; Wall and Davis, 1951; Glusman et al., 1953). Complete respiratory arrest in expiration has also been reported by Kaada (1951) and Kaada et al. (1954), on stimulation of points of amygdaloid nuclear complex. These were more pronounced from medial rather than the
lateral part of the nuclear complex. MacLean and Delgado (1953) while studying the behavioral responses of the unanaesthetised animals to electrical and chemical stimulation of different limbic regions observed certain respiratory effects. Stimulation of rostral part of amygdala and overlying cortex led to respiratory acceleration whereas stimulation of lateral nucleus of amygdala and uncus produced respiratory slowing or temporary arrest.

Turner (1954) observed apnoea in the lightly anaesthetised animals on stimulation of amygdaloid nucleus, stria medullaris and certain other adjoining thalamic structures and pathways. Arrest of breathing has also been recorded on stimulation of amygdala in unanaesthetised animals (Kaada 1951; Shealy and Pelle 1957) and in man (Liberson et al. 1951; Kaada and Jasper, 1952). Increase in rate of respiration with decreased or occasional increase in amplitude on stimulation of amygdala was obtained in unanaesthetised animals (Magnus and Lammers, 1956) and in animals under urethane anaesthesia (Koikegami and Fuse, 1952a and b). Inhibition of respiration in the inspiratory phase on stimulation of medial nucleus of deeply anaesthetised rat has been reported by Wood et al. (1958). Ursin and Kaada (1960) in their recent study on unanaesthetised animals noted alterations in breathing on stimulation of amygdaloid nuclei.

3) Body Temperature

The maintenance of temperature homeostasis in spite of the wide variations in the environmental temperature
suggests that the "body thermostat" is a precisely adjusted one. The role of nervous system in integrating the mechanisms regulating body temperature has been emphasized by many from time to time. It has been reported that lesions in nervous system are often accompanied by various disorders of temperature regulation. Sleep and wakefulness, emotions and muscular activity are well known to be accompanied by changes in body temperature. The hypothalamic thermodetectors are believed to exert a tonic influence on the relay system of the brain-stem from which much of the activity of the organism is governed. Since certain higher nervous regions are involved in these states of activity and body temperature has been shown to change with the various levels of activity, a relationship of changes in body temperature to these regions of the brain has been suggested.

The existence of thermoceptive structures in brain was reported by Kahn (1904) and such structures were shown to be localized near the corpus striatum (Barbour, 1912). As a result of experimental studies (Bazett, 1933; Ranson, 1940; Magoun et al., 1938; Blair, 1946; Fulton, 1949) the role of hypothalamus in the regulation of body temperature is much clarified, — the anterior part of hypothalamus dorsal to the optic chiasma and infundibulum being important in preventing abnormal rise in the body temperature and the posterolateral part in preventing abnormal fall in the same. Heating the hypothalamus causes vasodilation, sweating and hyperpnea (Magoun, 1938) while cooling it causes vasoconstriction and tremor. In the decorticate dog, though the
animal maintains a normal temperature, shivering occurs sooner than controls when exposed to cold. Probably cortex is more important in body-temperature regulation in man than in other species (Bard and Rioch, 1934 and 1937). The suggestion that the medulla oblongata contains thermo-sensitive structures influencing cutaneous blood flow (Barbour & Jelsma, 1931) and sweating (Hasana, 1930) has not been substantiated.

Delgado and Livingston (1948) observed that mechanical, thermal and electrical excitation of the orbital surface frequently results in a prompt temperature rise of 6° - 8°F in both hind extremities, only if the circulation to the limbs is left intact. If the posterior orbital gyri are ablated bilaterally, the temperature of the extremities in the chronic animals is higher than normal, and the response to cold is less pronounced and less prolonged.

Andersson (1957) reported shivering, peripheral vaso-constriction, and sometimes piloerection on electrical stimulation in or in the vicinity of the septum pellucidum of unanaesthetised goats. Animals exposed to heat showed inhibition of polypneic panting on such stimulations. Prolonged stimulation in room temperature caused a rise in rectal temperature of up to 0.5°C at which stage shivering was no longer seen as a result of stimulation. Showers (1959) reported marked drop in body temperature in majority of the animals after destruction of the cingulate gyrus.

Studies on body temperature in relation to these higher nervous regions do not seem to be adequate. It needs a much comprehensive attack on the problem to examine in
detail the role of various limbic structures, if any, in maintenance of temperature homeostasis in the body.

4) Gastrointestinal System

Lesions in the central nervous system and more often those in the neighbourhood of the walls of third ventricle, have been known for long to be associated with changes in the activity of the gastrointestinal tract. Rokitansky, a Viennese Pathologist (quoted by Fulton, 1955), noted as early as a century back that infections at the base of the brain were generally associated with profound changes in the gastrointestinal tract. It is, however, comparatively recently that the intimate relationship of limbic system to gastrointestinal activity has been reported by many workers.

Working on cats and monkeys, Bailey and Sweet (1940) demonstrated a decrease in tonus of gastric musculature on stimulation of orbital surface. Eliasson (1952) found that varying the distension of stomach changed the effect of cortical stimulation on gastric motility, although only quantitatively. He also elicited vigorous contractions of the stomach on electrical stimulation of the amygdala, whereas no alteration in gastric motility followed stimulation of the hippocampus. Koikegami and co-workers (1952) have reported the possible relationship of amygdala to gastrointestinal activity. They have shown that in general, stimulation of medio-basal group of amygdaloid nuclei produces inhibition of gastrointestinal movements. Changes in gastric motility have also been shown to be induced by stimulation of temporal
polar cortex (including part of pyriform cortex), the posterior orbital surface of frontal lobe (Babkin and Kite, 1950; Babkin and Speakman, 1950), and certain hypothalamic areas (Kurotsu et al., 1958). Penfield's group (1954, 1955) has, in spite of many thousands of cortical stimulations, found only the area around the insula and the bands of the sylvian fissure to be connected with gastrointestinal activity.

Ablation studies, on the other hand, as reported by Babkin and Kite (1950) indicate that removal of orbital surface does not effect gastrointestinal motility while cingulate seems to be the only part the removal of which increases gastric motility.

Production of gastro-intestinal lesions have been reported by stimulation and ablation of certain regions of limbic system. Heath (1954) demonstrated hyperaemic and ulcerative changes in gastrointestinal tract after producing lesions in septal areas. Similar mucosal changes were also observed by Sen (1957) by stimulation of anteromedial hypothalamus. French et al. (1957) showed that the group of animals exhibiting focal lesions in pyloric antrum, ulcers in the duodenum or diffuse changes in the stomach, had received excitation currents to a low mid line axis in the hypothalamus.

Studies on gastric secretory activity also reveal the possible role of limbic system in influencing such secretions. It has been reported that gastric acidity increases on stimulation of amygdala in unanaesthetised animals and this may be compared favourably with that after histamine alone.
Increases in acidity have been observed from stimulation of tuber cinereum and supraoptic and preoptic areas (Sheehan, 1940; Porter, 1953). Stimulation of the lateral surface of the frontal pole in dogs and in the unanaesthetised monkeys causes an increase in volume, in acid and in the pepsin content of gastric secretions.

(Davy, Kaada and Fulton, 1950). Using method for continuous registration of gastric pH, Klopper (1954) showed that on stimulation of an area just inferior to the anterior sigmoid gyrus in the cat, a definite decrease in gastric pH was obtained. Sen and Anand (1957) have confirmed that a marked increase in the volume of gastric secretion and its acidity (free and total) and pepsin contents is obtained by stimulation of amygdaloid group of nuclei, the tip of temporal lobe and the posterior orbital surface of the frontal lobe. Stimulation of anterior cingulate and hippocampus did not produce any such increase.

It is generally believed that excitatory and inhibitory fibres to the stomach run in both the vagus and splanchnic nerves (Eliasson, 1952). Bailey and Bremer (1938) without specially studying the gastric fibres involved, established the existence of vagal projections to orbital surface. Distension of stomach causing discharge of impulses in vagal fibres (Paintal, 1953 and 1954), visceral afferents in vagi carrying sensation of nausea and distension (McDonald and Chusid, 1956) and intestinal receptors inner-
vated by vagal afferent fibres (Iggo, 1957) have also been reported. Recently the central connections of these gastric vagal afferents have been undertaken in this laboratory. It has been shown that gastric impulses travelling centrally in vagi could be recorded in satiety region of hypothalamus, supra-optic area, orbital surface and amygdaloid region (Sharma et al., 1960). Changes in electro-encephalographic activity of some of these limbic regions like orbital surface, amygdala and hypothalamic areas have also been observed on increase of intragastric pressure by intragastric balloon technique (Sharma et al. - unpublished).

The relationship of various limbic structures to gastrointestinal activity is still not very clear. Some anatomical zones have produced dissimilar results in different hands. A systematic approach to map out the different areas of the limbic system is, therefore, proposed to be undertaken in the present work, and fractionate the responses as far as possible.

5) Blood Chemistry

Schrodinger (1945) advanced the concept that life, is related to metabolism and Sherrington (1946) defined mind as the manager of muscle. Heath (1954) in attempting to trace the manner in which mind evolved as the integrator of behaviour and to correlated behavioral characteristics with the evolution of nervous system, presented the following concept.

"The basis of life is metabolism. In all living organisms movement is directed towards the satisfaction of metabolic needs, but as organisms progress up the phylogenetic scale,
movement or behavior becomes integrated through higher levels of neuraxis. There are very few reports in the literature concerning the relation of this neuraxis to changes in blood chemistry.

Allot (1939) reported five cases in which there was retention of sodium and chloride in the presence of cerebral damage without kidney disease. Tokay (1931) described decreased salt output after stab wounds in the region of caudate nucleus.

Luetscher and Blackman (1943) reported high serum sodium and chloride levels and persistent cerebral damage in association with injury to the kidneys following sulphathiazol administration. Sweet and his colleagues (1948) reported severe and fatal metabolic disturbances after lobotomy. Heath et al. (1954) observed characteristic changes including depletion of body carbohydrate as shown by blood glucose and tissue glycogen measurements, marked decrease in plasma sodium and poikilothermia accompanied by a profound loss in body weight, after extensive lesions in the septal nuclei and the gray matter at the base of the lateral ventricles. Later studies by the same group of workers found similar changes after localized lesions produced stereotaxically. There is an occasional report in the literature of alterations in glycogen, and electrolyte metabolism after lesions of the rostral part of fore brain in man (quoted by Heath, 1954).

In a recent report on "The participation of the
limbic system in the development of Hepatic coma.* Kitaij et al. (1959) have blamed metabolic changes to be responsible for these derangements. Based on clinical and experimental observations, they put forward that the "hyperammonemic factor" induces mental and behaviour abnormalities by exciting the limbic system. "Liver-insufficiency factor" or liver refraction, on the other hand, seem to produce coma by depressing the activity of the brain-stem reticular activating system.

There is thus a growing importance being felt of the possible role of these nervous structures in regulating the blood chemistry, and also the changes in blood chemistry influencing these areas of the brain. In order to have a better understanding of such a relationship, various regions of the limbic system are proposed to be stimulated and ablated in a systematic way and see the effects produced on blood chemistry.

6) Endocrine activities

(1) A.C.T.H. secretion

The role of hypothalamus in regulation of the A.C.T.H. from the anterior pituitary in response to a stressing agent is well established by now. Difference of opinion as to the exact localization in the hypothalamus involved in this stress response has however been there (Hume and Wittenstein, 1950; Hume, 1953; Groot and Harris, 1950; Porter, 1953 and 1954; Laqueur et al., 1955; and Greer and Erwin, 1956). Anand et al. (1954) as a result of ablation studies in rats located this centre to be in the
anterior and medial parts of median eminence. This was later confirmed by Anand and Dua (1955) using stimulation techniques in cat.

Since states of emotional stress, such as anxiety, worry or excitement are potent stimuli in increasing the secretion of A.C.T.H., it has seemed probable for sometime that the cerebral cortex and the related limbic regions are in some way concerned with the release of A.C.T.H. It is only recently that attempts are being made to demonstrate the direct evidence regarding this relationship. Porter (1954) quoted by Harris (1955) has reported the following observations made on monkeys anaesthetised with cyclopropane. That the stress stimuli which increased the electrical activity of the tuberal and mammillary regions of the hypothalamus, activated also the anterior nucleus of the thalamus, and the anterior cingulate gyrus. The increased activity of these regions was dependent on the presence of intact hypothalamus. Electrical stimulation of the orbital surface of the frontal lobe resulted in a marked eosinopenia. Electrical stimulation in the hippocampal region, in particular the uncus, inhibited the eosinopenia which normally followed administration of adrenaline or operative trauma. Ganong et al. (1955) found a marked increase in plasma 17-OH corticosteroid secretion in dogs after 2 hours of psychic stress (immobilization) and prevention of such a response by lesions placed in the anterior median eminence.

Indirect evidence has also been presented by Koikegami and co-workers (1954 and 1955) showing generalized
atrophy of the endocrine glands following bilateral amygdaloïdectomy in young puppies.

MacLean (1955) has put forward the hypothesis that the frontotemporal region of limbic system may exert a discriminatory influence over the release of such hormones as ACTH by the hypothalamo-pituitary system during times of stress.

Mason (1950) provides evidence of a significant elevation of plasma 17-hydroxycorticosteroids following stimulation of Amygdala.

Investigating the role of central nervous system in regulating pituitary-adrenal function Okinaka et al. (1959) have suggested that posterior orbital surface and amygdaloid nuclear complex activates, while hippocampus suppresses ACTH secretion. Moderate increase of 17 OHC3 output from adrenal was observed following stimulation of the mid brain reticular formation. No such change in ACTH secretion or 17 OHC3 levels was produced by stimulation of anterior sylvian gyrus. Hypophysectomy completely abolished these responses. Story et al. (1959) attempted to study the adrenal cortical function after step wise removal of the brain in dog. It is reported that removal of brain down to the hypothalamus resulted in no diminution in the maximum adrenal cortical response following operative trauma as measured by 17-OH corticosteroid output.

(11) Gonadotrophin Secretion

Lesions in the hypothalamus have for many years been known to produce disturbances in sexual cycle of female
mammals. Stimulation on the other hand is known to result in increased secretion of gonadotrophic hormones (Harris, 1937; 1948; Haterius, 1937; and Markne et al., 1946). The disturbances produced have mostly been explained either due to lack of gonadotrophin secretion or its increased secretion, thus interfering with the ovarian secretions and ovulation. Bard (1940) reviewed the data regarding the site of action of ovarian hormones on the central nervous system in eliciting oestrous behaviour. Harris (1958) remarked that the hypothalamus has the potentiality of increasing or decreasing pituitary secretion and the results of these changes of glandular function may well be reflected in changes of behaviour pattern. The intimate relation between hypothalamus and various limbic structures in terms of various autonomic and visceral activities have been shown by many. It has also been suggested that limbic system may influence the pituitary trophic hormones including gonadotrophins through its connections with the hypothalamus which in turn influences pituitary. Klüver and Bucy (1939) observed striking manifestations of sexual behaviour of monkey after bilateral removal of temporal lobes. Similar changes have been reported by Gastaut (1952) and Schreiner and Kling (1953, 1954 and 1956) in cat, lynx and agouti and by Terzian and Dalle Ore (1955) in human male after temporal lobotomy. The hyper-sexuality developed after such lesions disappeared after castration (Schreiner and Kling 1956). Klüver and Bartelmez (1951) observed a condition resembling metropathia haemorrhagica in a monkey after lesions of frontal and temporal lobes, while Schreiner
and Kling (1953) reported persistent oestrus in the cat. Green (1954) recorded a change in the electrical activity of the hippocampus in a conscious rabbit during sexual arousal. Richter (1956) quoted by Harris (1958) reported that lesion in amygdaloid nuclei of wild rat tend to restore rhythmic activity cycles which are, in all probability, related to the oestrous cycle of these animals. Green et al. (1957) observed changes in sexual behaviour of male cats only after lesions in the pyriform cortex and amygdala while, the female cats did not show any such change.

Thus as a result of recent experimental and clinical observations evidences are accumulating to show the participation of certain limbic structures in the elaboration of various behaviour patterns of the body. It is, however, not clear whether such behavioral changes observed are secondary to hormonal changes brought about by these limbic structures or the limbic structures are themselves primarily responsible for these behavioral disorders. It would be worth investigating the problem from that angle.

7) Other visceral and somatic responses.

(1) Autonomic responses.

During the course of experimental studies on limbic system, particularly during stimulation of different limbic regions, some of the general autonomic responses like piloerection, salivation, urination, defecation and pupillary changes were observed by a number of workers.

More attention was focussed towards localization of these responses when it was realised that a variety
of such complex visceral phenomena may also be observed in temporal lobe seizures in human patients. Rioch and Brenner (1938) observed salivation on stimulation of olfactory tubercles and pyriform cortex, Kaada (1951) reported salivation with associated licking, chewing and swallowing movements on stimulation of olfactory tubercle and the adjacent posterior orbital and anterior insular areas in monkeys and cats. Even in Asiatic pangolin who uses its long and extensile tongue with profuse saliva in catching ants and insects as its diet, the olfactory tubercle is found to be extremely well developed (Chang 1949 quoted by Kaada 1951). The possibility of these large olfactory tubercles serving as more elaborate control of the tongue and mucous glands is suggested. Similar reports were made by Edinger as early as 1908 who defined olfactory tubercle as "ein centrum des oral sinnes".

Showers and Crosby (1958) elicited salivation on stimulation of cingulate cortex. Salivation of a marked degree, pilocerection and secretion of nasal and lachrymal glands has also been reported on stimulation of amygdaloid nuclei by a number of workers (Baldwin et al., 1954; Gastaut, 1952 and 1953; Gastaut et al., 1957; Kaada et al., 1954; Koikegami et al., 1955; Lammers and Magnus, 1955; MacLean, 1952; MacLean and Delgado, 1953; Naquet, 1953; Takahashi, 1951; and Vigouroux et al., 1951). Kremer (1947) observed bladder contractions on stimulation of posterior part of the cingulate cortex in dogs. The same was later reported by Kaada (1951) and Smith (1949) from pyriform area in monkeys and by Kaada (1951) in cats and dogs. Henneman (1948) on the other hand observed both contraction and relaxation of the bladder
from these areas in cats. 

Stimulation of posterior part of pyriform cortex occasionally produced defecation in cats, dogs and monkeys (Kaada, 1951). Both defecation and micturition are reported to result from stimulation of amygdaloid nuclei (Gastaut et al., 1952; Gastaut, 1952; Kaada, 1951; Kaada et al., 1954; MacLean, 1952; MacLean and Delgado, 1953; Naquet, 1953; Vigouroux, 1951).

Siebens and Woolsey (1946) elicited pupillary dilatation on stimulation of the cingulate gyrus of the cat. Smith (1945), Ward (1946); and Showers and Crosby (1956) reported pupillary dilatation and piloerection from the anterior cingulate. Sachs et al. (1949) on the other hand demonstrated pupillary dilatation from the posterior orbital gyrus in monkey. Similar responses were elicited from septum, midline group of thalamic nuclei, subthalamus and a large part of the midbrain by Hodes and Magoun (1942, 1942a). Pupilloconstriction has been observed by Hodes and Magoun (1942a) and Kaada (1951) by stimulation of a narrow zone immediately surrounding the genu of the corpus callosum.

Daly (1958) reports that epileptic discharges in the region of temporal lobe and uncus may evoke olfactory or gustatory experiences, rhinostomal sensations, salivation or masticatory movements. Magnus, Penfield and Jasper (1952) have suggested that the region of island of Reil and the adjacent parts of temporal lobe and uncus form a cortical area for Edinger's "Oral sense". They further suggested that the impulses for taste, smell, and oral tactile sensations
converge in this region and from it corresponding motor effects like mastication and salivation result. MacLean and Delgado (1953) observed lachrymation, salivation, piloerection, pupilloconstriction or dilatation and more rarely, urination and defecation on stimulation throughout the frontotemporal region. Ward (1948) showed that stimulation of the superolateral surface of frontal lobe gives rise to bilateral pupillary dilatation in the monkey.

(ii) Somatic responses.

Kremer (1947) was the first to observe tonic movements of extremities, trunk and head on stimulation of anterior limbic regions in lightly anaesthetised dogs. Similar responses were later reported by Kaada (1951), Sloan and Kaada (1953) and Ward (1948) from anterior cingulate; by Kaada (1951) and Sachs et al. (1949) from posterior orbital, and by Frontera (1956), Kaada (1951) and Kaada et al. (1949) from anterior insular and temporal polar cortex. Showers and Crosby (1956) tried to map out the whole of cingulate gyrus. They observed a pattern of somatotopic movements obtained by stimulation of the anterior cingulate region which may be elicited in a reversed order from the stimulation of the posterior cingulate region.

Movements involving facial, eyelid, orbital and oral muscles and jerky movements of neck and shoulder have also been reported by a number of workers from various limbic structures on stimulation in anaesthetised and unanaesthetised animals. (Kaada, 1951, 1953; Sloan and Kaada, 1953; Baldwin
et al. 1954; Takahashi, 1951; Vigouroux et al. 1951; Shealy and Feele, 1957 and Frost et al. 1958). On the other hand, Lennox and Robinson (1951) observed that on stimulation of anterior cingulate gyrus in lightly anaesthetised animals, there was the arrest of spontaneous movements. Kaada (1953) has stressed the contraversive turning of the head as a response from the amygdala and this has been suggested as of diagnostic importance in temporal lobe epileptic seizures (Magnus et al. 1952).

Anatomical (Clark, 1947; Meyer, 1949), physiological (Fox, 1944, Berry, 1952) and clinical observations (Penfield, 1951), all concur in placing the cortical representation of the sense of smell in the pyriform areas.

Coordinated oral responses related to eating are also produced by stimulation of limbic system. It has been shown that oral-visceral motor functions pertaining to smelling, tasting and eating including eating automatisms, are represented in fronto-temporal regions (Schaltenbrand and Cobb, 1939; Rieoh and Brenner, 1938; Smith, 1944; Sugar et al. 1948; and MacLean and Delgado, 1953). The cortical representation overlapping fronto-temporal region for the oral tactile sense has given an added importance to this region in as much as it could be expected to correlate the oral-visceral activities of the animal.