7. Higher Nervous Functions

7.1 Consciousness

Each morning we wake up - that is, we become conscious of the external world and of our own thoughts and emotions. This state of being conscious has so far defied psychological and physiological explanation.

Being conscious means being aware of our identity, of our past and present, and possessing the notion of the future. It evidently includes outward-looking aspects - awareness of others, aesthetic and ethical judgements, the ability to express one's thoughts and ideas - as well as inward aspects - our emotions and fantasies.

There is a variety of levels of consciousness. We can pay close attention (a heightening of consciousness), or day-dream (a turning inward which to the observer is a diminution of consciousness). Finally consciousness is regularly lost every night as we go to sleep and as miraculously regained as we wake up.

The Electroencephalogram

It is possible, by recording the electrical activity of the brain, to define what conscious state a man is in. These electrical records are the algebraic summation, at the point on the surface at which the measurements are made, of the changes in potential resulting from current flow between dendrites and cell bodies in the underlying brain. This current is a consequence of the excitatory and inhibitory postsynaptic potentials. Note that the magnitude of the potentials recorded (in microV) is much attenuated, reflecting the fact that the electrical changes have been transmitted through a volume conductor.

The normal EEG in the awake and alert state shows irregular, low-voltage waves (30-80 microV) of high frequency. The trace is said to be *desynchronized.* If a man is bored or closes his eyes, waves with a frequency of 8-10 Hz are recorded, particularly in *occipital leads,* indicating *synchronized* activity of neurones. This is termed the *alpha rhythm.*

Alpha and other synchronized rhythms are thought to be induced by activity of the thalamic nuclei. Although decortication leaves thalamic activity unimpaired, lesions in the thalamus or deafferentation of a related cortical area abolishes the rhythm in that cortical area. Direct recording of electrical activity in the thalamus indicates the presence of multiple spontaneously-active pacemaker neurones, which are influenced in their firing rates by brain-stem signals.

Variations in the Level of Consciousness

Consciousness is associated with brain activity. Anaesthetics, injury, metabolic poisons and disease regularly confirm that impairing brain activity impairs consciousness. There is considerable evidence hat brain-stem activity helps to determine the level of consciousness and is essential for cortical function.

Victims of the encephalitis lethargica initially suffered from insomnia but as the disease progressed they fell into a deep sleep from which they could only briefly, and with difficulty, be aroused. At post-mortem there was a lesion in the mid-brain in the grey matter adjacent to the third nerve nucleus and sometimes involving it.

Lesions in animals had the same effect - the animals becoming somnolent and developing a synchronized EEG pattern. Electrical stimulation in the mid-brain grey matter would arouse normal sleeping animals, at the same time converting their EEG to the waking pattern.

Anatomical attention was then redirected to this region of the mid-brain, which can be though of as similar to the grey matter of the spinal cord. This, and similar regions in the pons and medulla, were described by early brain anatomists collectively as the *reticular formation.* Reticular means net-like, and refers to the finding of nests of cells (small brain-stem nuclei) enmeshed in fibre tracts. The region has very many of these nuclei, only a few of which are large or distinctive enough to be named. One such is the *locus caeruleus* which is one of the noradrenergic-containing groups of cells found in the pontine reticular formation. Another recognized group comprises the *raphe nuclei*, which lie in the midline in the pontine region.

Some reticular neurones lying largely in the medulla send descending axons to the spinal cord to excite or inhibit motor neurones. Others, largely in the pons and mid-brain, send ascending axons to excite or inhibit thalamic cells. Some of the reticular neurones are very large, presumably because they have to support very long axons; some giant cells, for instance, have a bifurcating axon, one branch passing to the thalamus and the other to the spinal cord.

It is possible to record from reticular nuclear cells and find that they are excited by skin, visual, auditory and olfactory inputs - a truly polysensory input. What can be the meaning of such a system? It convey the message that a stimulus has occurred.

The *reticular activation theory* says that the signals from the reticular formation are used to vary the activity of the thalamic pacemakers, and thus cortical neurone excitability. The non-specific nuclei of the thalamus (including the intralaminar and anterior thalamic nuclei), some of which receive input from the reticular formation, project to wide areas of the association cortex. The thalamic neurones of the non-specific system have two effects. First, through their axons, they excite cortical cells. Secondly, they have a complex interaction with the specific thalamic nuclei via axon collaterals to interneurones which in the drowsy state inhibit he neurones of the specific thalamic nuclei. Upon arousal or alerting, however, this inhibitions is removed so that the specific thalamic nuclei can conduct their sensory information more easily to the cortex. Incoming signals from arousing stimuli are also routed through the reticular formation to the hypothalamus. The hypothalamic effects include release of adrenaline which prolongs arousal, first and rapidly, by exciting the reticular neurones and, secondary and more slowly, by a blood-borne action on cortical neurones.

7.2 Sleep

As one goes to sleep the alpha rhythm, characteristic of the drowsy state, appears and is later replaced by low-amplitude theta waves of a slower frequency (4 to 6 per s) which characterize stage 1 sleep. As sleep becomes deeper (as judged by the difficulty of awakening the sleeper), occasional bursts of fast waves (12 to 15 per s) called 'sleep spindles' are seen, signalling stage 2 sleep. Stage 3 is characterized by the presence of high-amplitude delta waves with a frequency of 1 to 2 per s and the presence of K complexes (bursts of more rapid waves). Stage 4 is characterized by a trace consisting almost entirely of large delta waves.

During a particular phase of sleep large-amplitude rapid (60 to 70 per s) saccades in eye movement are recorded which have been given the name *rapid eye movement (REM) sleep* to this stage. Moreover in sleep the pupils of the eyes are constricted but sudden dilatation may accompany REM.

Closer examination has shown that the REM state is accompanied by a number of signs of excitement and stress. For instance, there is a marked variation in the pulse and blood pressure and irregularity in the respiration, accompanied by secretion of corticosteroids. Furthermore a cycle of penile erections occurs, beginning with each REM period and ending at its end, and testosterone secretion is increased at night in association with REM sleep.

It appears that we all spend some time every night in the two type of sleep, *'slow wave (SW)'* sleep and REM sleep. Young adults normally spend some 16 to 18 hours awake. The remaining hours are divided between the SW and the REM sages, stage 4 coming early in the night and REM sleep becoming increasingly frequent as the night progresses.

SW sleep develops with maturation of the nervous system.

REM Sleep and Dreaming

Subjects awakened from REM sleep almost invariably report that they have been dreaming. Apparently we all dream although we do not always recall our dreams.

Neural Basis of Sleep

Sleep has been attributed to the absence of arousing stimuli to the reticular formation and therefore to thalamus and cortex. In man, removal of all external stimuli leads to hallucinations rather than sleep. More probably, sleep is produced by active inhibition of that part of the reticular formation responsible for arousal. Hess showed that there are a number of sites in the brain which, if stimulated, will induce the animal to go to sleep in a natural manner. The best characterized of these sites lies in the forebrain in the region rostral to the hypothalamus between the anterior commissure and the optic chiasm - the *preoptic region.* Lesion here make animals permanently sleepless and the region contains a population of neurones which discharge maximally in both SW and REM sleep.

The preoptic region has substantial efferent projections to the mid-brain, particularly to its reticular formation.

The Need for Sleep

SW sleep is needed for bodily repair. Growth hormone is only secreted during SW sleep. REM sleep is concerned with repair of mental tiredness. Long sleepers tend to be significantly more introverted, anxious and depressed than short sleepers. Short sleepers go to sleep more quickly, spend less time in stages 1 and 2 and in REM sleep but spend the same time in the deepest stages (3 and 4) of SW sleep.

Sleep Disorders

Sleep-walking (*somnabulism*) and bed-wetting (*nocturnal enuresis*) have been shown to occur during periods of arousal from SW sleep. They are not associated with REM sleep. Episodes of sleep-walking are more common in children and occur predominantly in males. They may last several minutes. Somnabulists walk with their eyes open and avoid obstacles, but when awakened they cannot recall the episodes.

Narcolepsy is a not uncommon disease of unknown cause in which there is an eventually irresistible urge to sleep during daytime activities. In some cases, it has been shown to start with the sudden onset of REM sleep, whereas REM sleep almost never occurs without previous SW sleep in normal individuals.

Some adults have *sleep apnoea* - a condition in which breathing ceases completely a number of times during the night. When this happens the subject wakes, takes a few breaths and falls asleep.

Nocturnal myoclonus is characterized in sudden contractions of muscle groups, commonly of the legs, sometimes of the head, during sleep. It is akin to epilepsy.

7.3 Disturbances of Consciousness

Damage to the mid-brain, pons, medulla or cortex may result in unconsciousness due perhaps to disruption of the reticular activation system. It may be transitory, in which case it may be a form of epilepsy or of concussion. *Concussion* implies a brief loss of consciousness due to head and brain injury. It may be prolonged - *coma.* Coma implies failure of either the association areas of both cerebral hemispheres, if the damage is very extensive, or of the ascending reticular formation of the brain-stem and diencephalon, the structures which keep the cortex 'awake'.

Disturbances of brain-cell metabolism as in hyper- and hypoglycaemia, anoxia or following a drug overdose, may produce coma by affecting both the brain-stem and the association-area neurones. Most forms of coma are accompanied by a fall in the oxygen consumption of the brain. For instance, the blood supply may fall to 60% of normal during anaesthesia and to about 50% of normal in a diabetic coma.

If a patient does not know who he, where he is and what time it is he is *disoriented.*

Epilepsy

Epilepsy may be defined as a recurrent, paroxysmal, transitory disturbance of the CNS that is characterized by uncontrolled neural discharge. Epileptic seizures generally involve total or partial loss of consciousness and may be accompanied by uncontrolled motor reactions.

It may be classified as generalized or focal in origin. *Generalized* or *centrencephalic* epilepsy is a term used to cover a very large group of patients in whom no cause for the disorder can be found. It has its origin in disorders of the activating system in the brain-stem or thalamus. *Focal epilepsy* arises when the seizures begin in a localized area of cerebral cortex.

Two varieties of generalized epilepsy are relatively common - grand mal and petit mal. *Grand mal* seizures are characterized by an abrupt loss of consciousness and violent involuntarily contractions of skeletal muscles. Together these phenomena are termed a *convulsion.* Many patients have mild symptoms which precede the attack, the *aura.* Many forms of aura have been described - tingling or numbness in the limbs, visual or auditory hallucinations or sudden emotional changes such as fear. The aura is followed by the convulsion and is usually the last thing the patient remembers. First, the patient stiffens and is apparently thrown to the floor, respiration stops and the pupils dilate. This is the *tonic phase* lasting 10-30 s in which the patient often lies with the legs fully extended and the arms flexed and abducted as if decorticate. It is followed by a *clonic phase* with severe jerking movements and, commonly, emptying of the bladder. After the convulsion the patient appears relaxed, drowsy and may complain of headache. This stage lasts 30-60 min and is often followed by sleep. During a seizure the EEG shows high-voltage spiking during the tonic phase which during the clonic phase becomes mixed with a high-voltage slow component. Electroconvulsive therapy (ECT) produces convulsions of a grand mal type but the motor components are in practice prevented by anesthetizing the patient and administering a muscle relaxant.

Petit mal usually affects children rather than adults. There is no warning, no aura, but brief periods of unconsciousness or altered consciousness during which the patient may stare blankly; the eyes may roll upwards until the pupils are hidden under the lid. Episodes last 5-30 s and a patient may stop what he is doing and restart after the seizure without apparently being aware of what has happened. The EEG of petit mal shows a characteristic wave form. There is an alteration between high-voltage waves of short and a long duration (spike and dome complex).

When seizures begin in a localized area of the cerebral cortex, *focal* epilepsy results. The commonest form in adults is temporal lobe or psychomotor epilepsy. Here the epileptic focus is located in the temporal lobe. he seizure is characterized by automatic purposeful reactions such as chewing, and smacking the lips. There are no convulsions and the patient may or may not lose consciousness. It is important to remember that focal seizures have recognizable underlying pathology whereas generalized seizures may not.

Jacksonian epilepsy, named after Hughlings Jackson who first clearly described it, is a term used to describe focal motor seizures beginning in the motor areas of the cerebral cortex. Such seizures usually begin with a twitching, most often of the thumb or of a finger, a toe or the angle of the mouth. These regions are the most widely represented in the motor cortex. Thereafter the 'march' of the seizure is that expected if the lesion had radiated out from these areas over thee rest of the motor cortex. Focal sensory seizures are also known.

The classification of epilepsy has recently changed to take account of the finding that many patients with recurrent paroxysmal transitory disturbances of the CNS do not fall into the traditional categories.

1. Generalized seizures. Patients have bilateral signs and symptoms without local onset. Classical grand and petit mal both fall into this class.

2. (a) Partial seizures. Patients have their signs and symptoms beginning locally. Jacksonian epilepsy falls into this class. (b) Partial complex seizures. Patients have impaired consciousness, complex hallucinations and may demonstrate automatism (a series of apparently purposive movements of which the patient is unaware) during the seizure. Temporal lobe epilepsy falls into this class.

3. Unclassified. Patients fall into this class if there is incomplete data for classification into classes 1 and 2.

7.4 Learning and Memory

'Motor' memories may survive and be added to when other types of memory are badly impaired. The 'recognition' and 'recall' types of memory are not akin to a photographic record but what is remembered is a reconstruction based as much on what was expected as on what actually happened. Accordingly witnesses are notoriously fallible.

People with so-called 'photographic memory' can recall at will an image of what they have seen, apparently localized in space in front of their eyes. The image is known as an *eidetic image*. Eidetic imagery is an alternative means of storing information, distinct from, but not more effective than, ordinary memory.

Memory for verbal material indicate that there are short-term ('primary') memories of snippets of information looked up immediately before use (i.e., telephone numbers), longer-term ('secondary') memories of much-rehearsed material, and memories which last a lifetime ('tertiary' memory), such as one's name and important life events. Recently after-images have been brought into this scheme, it being realized that they are epiphenomena of the initial step in memory (sensory memory).

Sensory memory refers to that brief period when information has reached receptors and is about to be sent on to the CNS. Information presented to the eyes can be evaluated and give rise to reflex responses before it is 'perceived'. The after-images seen when one looks at an object and then away from it may last about 250 ms, decaying over this period. Apparently the memory trace is destroyed by fresh incoming information. The capacity of the visual sensory memory for after-images appears to extend to about sixteen or seventeen items. A sensory memory has also been demonstrated in the auditory system.

For a material to be remembered it must have been sequentially in sensory, primary, secondary and perhaps tertiary memory.

Characteristics of Short-Term (Primary) Memory

These are (i) small capacity, (ii) short duration, and (iii) storage as words.

(i) Relatively few items can be recalled immediately after a short exposure (visual or aural).

(ii) Primary memory decays in a few seconds.

(iii) The material is coded in words.

Primary memory is thought to be represented in the nervous system by circulating nerve impulses, because an insult which disrupts the functioning of neurones prevents any memory of events which take place a short time before. Parietal lobe lesions in the association areas for auditory information can be associated with normal intelligence but a marked decrease in the capacity of the auditory primary memory.

Characteristics of Long-Term (Secondary and Tertiary) Memory

These are (i) large capacity, (ii) long duration, and (iii) organization.

(i) The storage capacity of secondary and tertiary memory is presumably very large though no quantitative estimates are available.

(ii) It appears that tertiary memory may be permanent.

(iii) Words which have a similar meaning are confused rather than words with a similar sound, implying that the organization is semantic and relational.

Secondary memory is notoriously difficult of access. There is much evidence that interference from material learnt before (*proactive inhibition*) or afterwards (*retroactive inhibition*) produces forgetting. Proactive inhibition appears to be the more troublesome. Tertiary memory appears to be easy of access.

Secondary and tertiary memory are thought to be represented in the actual structure or pattern of the CNS for they remain after neural insults which have destroyed primary memories.

Neurological Basis of Memory

Memory is disordered by injury to those structures seen as forming a fringe on the medial side of each hemisphere, around the brain-stem, hence the name 'limbic' system. The structures concerned are many synapses away from the primary sensory or motor pathways and receive information from the overlying cerebral cortex which, after processing, is directed back to the cortex. The *limbic system* comprises parts of either frontal lobe, particularly the cingulate gyrus, which lies above the corpus callosum, the hippocampus on either side, the septal nuclei, the amygdaloid nuclei, the hypothalamus and the non-specific thalamic nuclei including the anterior thalamic nucleus. The hippocampus lies on the medial wall of the temporal lobe bordering the inferior horn of the lateral ventricle. It is a layered structure like the cerebral cortex but of a simpler cellular pattern. The amygdaloid nucleus lies in the same region just in front of the hippocampus and in front of the inferior horn of the lateral ventricle. The septal nuclei lie in the midline anterior to the hypothalamus between the lateral ventricles and under (ventral to) the corpus callosum, the genu of which forms their anterior boundary. A large fibre bundle known as the fornix takes origin from the hippocampus and overlying cortex on each side. This bundle arches forward underneath the corpus callosum accompanied by a similar but much smaller bundle of axons (stria terminalis) from the amygdaloid nucleus. The fornix and stria terminate in the septum and hypothalamus, and the fornix also terminates in the mammillary bodies of the hypothalamus which in turn project to the anterior thalamic nuclei. These in turn project back to the cerebral cortex.

The integrity of the limbic system is essential for long-term memory. Bilateral damage to certain parts of the hippocampus, fornix, mammillary body, medial hypothalamus or those parts of the thalamus connected with the mammillary bodies, has the same effect, namely a remarkably severe and persistent disorder of memory (amnesia).

Of all the limbic structures, damage to the hippocampus causes the most severe amnesia.

Penfield found that when he stimulated particular points in the temporal lobes overlying the hippocampus, his patients reported that fragments of past experiences seen, heard or felt long ago, were being re-experienced and, moreover, at the same rate as originally.

7.5 Speech

Speech, together with its associated activities (reading and writing), is a most complex phenomenon. Basically, it is the conveying of meaning by means of symbols, usually spoken, sometimes written. It is necessary to distinguish the production of voice (*phonation*), the shaping of voice into words (*articulation*), and speech proper, which implies meaning and understanding. In one sense speech is a motor activity involving control of the labial, lingual, pharyngeal, palatal and respiratory muscles. Motor activities in general result from plans made in association areas, which are further elaborated by the basal ganglia and cerebellum and relayed to the ventrolateral thalamus. A final relay to the motor cortex brings appropriate motor neurones and thus muscles into action. The motor aspects of speech do not differ from other motor activities except in the planning stage, which is complex.

The speech is unique amongst other motor activities in that its higher control depends on the integrity of only one of the two cerebral hemispheres - *the dominant hemisphere*, in most people the left. This hemisphere also controls the right hand but cerebral dominance is not necessarily paralleled by appropriate handedness. Tests have shown that 95% of righthanded and 50% of left-handed people have their speech centre on the left. The production of speech thus involves subcortical and motor cortical components and also a component from association areas. Difficulties in speaking are termed *dysarthrias* if they involve the motor apparatus in the strict sense and *aphasias* if they involve the unique one-sided cerebral control.

A characteristic *dysarthria* occurs in many diseases, such as the scanning speech of cerebellar disease and the slow slurred speech of Parkinson's disease. While there may be some temporary disturbance of articulation, a permanent dysarthria does not commonly occur with the hemiplegia following a cerebral vascular accident because the muscles of the palate, pharynx and vocal cords are bilaterally innervated through the vagus and glossopharyngeal nerves. Bilateral loss of cerebral control of the medullary cranial nerves, on the other hand, causes a severe dysarthria as well as numerous other signs and symptoms (*pseudobulbar palsy*).

Lesions of the areas important for the generation of speech leads to aphasia, which literally means 'without speech' or better, dysphasia.

There are two major and many minor forms of aphasia. The commonest, *'motor'* or *'Brocca's aphasia'*, is named after Brocca who noticed that patients with a right-sided hemiplegia had a poorly articulated speech produced slowly and with great effort and abnormal in rhythm and intonation. For these reasons it is sometimes called a *non-fluent aphasia.* The speech content has been compared to a telegram in that patients can name objects and produce single words but have difficulty with sentences, coming to grief on the connecting words. These patients have trouble in reading and find writing difficult or impossible. Their comprehension appears unimpaired.

Wernicke described patients with normal articulation, rhythm and expression, and correct grammar who had great difficulty in finding the correct words. The patients were unable to understand spoken or written language. In severe cases they might produce a grammatically correct but meaningless flow of language. This is *Wernicke's* or *sensory aphasia.* Such patients have lesions involving the posterior part of the temporal lobe.

Wernicke's and Brocca's areas are joined by a bundle of nerve fibres called the *arcuate fasciculus.* Patients with lesions in this structure have *conduction aphasia.* Such patients can comprehend the speech of others but cannot repeat it. Their own speech is fluent, like Wernicke's aphasia, full of circumlocutions and of errors in word use.

More restrictive language defects arise when the speech area is disconnected from the cortical representation of one particular modality. In these cases a patient may be able to name an object presented in one sensory modality but not when it is presented in another (*anomic aphasia*). Speech itself is fluent and comprehension intact.

Emotional speech. The sounds made by animals as the result of strong emotion are akin to the expression made by man in similar excited states. Such sounds are controlled by a different part of the brain from the part of the brain involved in true speech. The production of such sounds is controlled from the limbic system in animals. There is some evidence that lesions in the right (non-dominant) hemisphere may cause its loss.

7.6 Organization of Behaviour

Control of Goal-Directed Behaviour

That part of the frontal lobe anterior to the premotor area and extending to the orbital surface (prefrontal cortex) is thought to be the site of integration of the information about the external world, sent to the cortex along the visual, auditory and somatosensory pathways, with the information about the internal world relayed from the hypothalamus and the limbic system. Behaviour in turn is thought to reflect the integration of this information within the prefrontal cortex.

Emotion

It is convenient to consider the *limbic system* as the site a which emotional one and its expression are generated. For instance, aggressive behaviour has been reported in a patient during stimulation of one of the amygdaloid nuclei through implanted electrodes, while bilateral amygdaloidectomy has resulted in an apathetic individual. Undercutting of the cingulate gyrus (cingulotractotomy) has been used in severe chronic depression which does not respond to any other form of treatment.

In contrast to the feeling of emotion, it is known in some detail how emotions are expressed through mechanisms involving parts of the frontal lobes of the cortex, the limbic system, the hypothalamus and the autonomic and somatic systems controlled by the hypothalamus. We can distinguish two basic states, (a) excitement and (b) alarm or worry. In the first category we can further distinguish anger, joy, lust, and in the second, worry, depression, anxiety or fear.

Motivation

Stimulation of certain areas of the brain can be used as a reward for appropriate behaviour in animals. The septal nuclei and to a smaller extent the cingulate cortex and the hypothalamus, for example. Also, hippocampus, but to a lesser extent. The most remarkable area was the *median forebrain bundle* in the lateral hypothalamic area which, amongst its other functions, connects the hypothalamic nuclei with the septal nuclei rostrally and with the mid-brain caudally.

Subcortical Control of Behaviour

Goltz demonstrated that a decorticate dog still showed its full range of emotional responses. The *hypothalamus* is the highest level of the nervous system needed for the display of emotional, sexual and gustatory behaviour and hypothalamic stimulation can evoke his behaviour. Interestingly, acting-out of the behaviour outlasts the stimulation, which appears to be only a trigger. Furthermore the hypothalamic neurones control not only autonomic neurones and the pituitary but must also have access to motor neurones, probably through reticulospinal pathways originating in the mid-brain. Certainly it is possible by mid-brain stimulation to evoke behavioural acts but these displays differ from those evoked by hypothalamic stimulation in that they do not outlast the stimulation.

Limbic structures control and organize hypothalamic functions so that behaviours are expressed in appropriate situations and ways. The amygdala appear to have, as one function, control of what is eaten and when. The medial amygdala stimulates eating and lateral prevents. After lesions of the amygdala animals and men will put anything in their mouths. The septum, too, appears to have functions connected with coupling of food intake to metabolism and the regulation of taste preferences.

Role of the Corpus Callosum

The corpus callosum is a large bundle of, for the most part, myelinated axons which have their origin in one hemisphere and pass to equivalent points as well as to other areas in the opposite hemisphere. All regions except the primary visual, primary acoustic and foot and hand areas of the pre- and postcentral gyrus are linked in this way.

The function of this largest of commissures was unsuspected even after its section became a treatment for otherwise intractable epilepsy. Sperry and colleagues in the 1960s clarified the function of the corpus callosum when they devised techniques which tested each hemisphere separately.

The corpus callosum thus transfers information and this transfer can be of acoustic and somatosensory as well as of visual information. However, not all interhemispheric transfer is through the corpus callosum. Discrimination of brightness is transferred through mid-brain commissures and the anterior commissure can also serve as a link for certain functions.

It is known that language functions are confined to one hemisphere and in Sperry's patients this was always the left. Verbal commands, then, were only obeyed by the muscles controlled by the left hemisphere. A patient, for instance, could not raise his left arm on command, nor could such a patient describe stimuli applied to the left side of his body.

There is no doubt that the left hemisphere in those patients was conscious. What of the right? The right or non-dominant hemisphere has memory, can pay attention and has the ability to perform complex tasks. It cannot control speech or writing but a few simple words or emotions can be expressed in response to stimuli that are private to it.

The dominant hemisphere codes verbally and performs poorly if this coding is difficult. The non-dominant hemisphere, in contrast, appears to appreciate shapes as a whole. Faces, which are difficult to describe in words, are recognized by the non-dominant hemisphere. Indeed, *prosopagnosia* which is usually the result of a non-dominant hemisphere lesion, is a disorder in which familiar faces cannot be recognized. In man the non-dominant hemisphere displays abilities which suggest a pictorial form of thought and a level of functioning which on its own terms is equivalent to the abilities of the hemispheres of other animals. It must be concluded that both hemispheres are capable of displaying attributes of consciousness and that consciousness is unified by the corpus callosum.