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Consciousness: Clinical and Beyond

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In my professional life as a neurosurgeon, from its very inception, the single most pervading clinical feature of concern was related to consciousness. The various afflictions of the brain-injury, infection, stroke or tumour-affected consciousness of our patients. Evaluation of the state of consciousness (or the lack of it), its grading, its diagnostic and prognostic significance were our constant concern. An understanding of the neural substrate responsible for it and the pathophysiology underlying its disturbance, constituted an important part of our intellectual pursuit. This was all the more so, because of the then current excitement in this field as a result of the physiological studies of the "arousal" system in the brainstem by Magoun (1952) and Moruzzi & Magoun (1949), and in the upper regions of the brain (thalamo-cortical) by Jasper (1949), the anatomical studies of the reticular formation by Brodal (1957) and Dr Penfield's reactivating the stored "stream of consciousness" by electrically stimulating the temporal lobe cortex of some epileptic patients (Penfield 1952, 1955). These were landmark events in the scientific pursuit of study of consciousness of the time.

Beginning my neurosurgical training under Professor Kristiansen in Oslo, Norway, whose studies on "Commotio Cerebri" (Concussion) had aroused renewed interest in the pathogenesis of unconsciousness in head injured patients (Kristiansen 1949) was, no doubt, responsible for prompting me to initiate clinico-pathological investigations on role of the brainstem in disturbance of consciousness in such patients. Over the years this interest increased to encompass several other aspects of the main theme: Consciousness. Reflecting on the clinical encounters with a wide range of patients with brain disease made one realise that there are many more aspects of consciousness than those of day to day concern to the neurosurgeon. I am fully conscious of the fears once expressed by Sir Charles Symonds, "I reflect with apprehension that a great subject can revenge itself shrewdly for being too hastily touched". No doubt consciousness, in its broadest connotation, is a great subject. I am, personally, not aware of any other problem which has been the subject of study by followers of so many disciplines. Thus not only biologists, neuroscientists, psychologists, psychiatrists and cognitive scientists, but physicists, chemists, mathematicians and more recently computer scientists and above all philosophers and sages, have all been attracted by this subject. Nevertheless, I have dared to share with you some experiences and thoughts on this subject, not withstanding the fact that my personal contributions in the field are trivial and add little to the vast information already available on the subject. Following the tradition of the Anniversary General Lecture, I would summarise some of our studies to provide a background for the discussion that follows.

Clinical Observations on Head Injured Patients

Diagnosis and Surgical Treatment of Severe Craniocerebral Injuries (Kristiansen & Tandon 1960)

In an uncomplicated patient of concussion, there is a transitory reversible impairment of consciousness. A clinical study of these patients unmistakeably suggests that recovery from coma to full consciousness depends upon progressively increasing integration of the activity of different regions of the brain. During the completely unresponsive state, immediately after injury, there are associated features like cardio-respiratory, pupillary changes and abnormalities of muscle tone and reflexes suggestive of involvement of the brain stem. As recovery sets in sequentially these associated features revert to normal, the patient starts to respond to painful stimuli of decreasing intensity first with only reflex movements, then by opening eyes, looking around, still not comprehending nor manifesting evidence of any awareness. A little later awareness seems to improve but confusion is evident. He may or may not recognize known persons around him, is not sure of his whereabouts or even the date or time. With further improvement he may recover full voluntary control, but he may act as a pure 'automaton'. When speech returns, the contents of his thought are rudimentary and restricted. Later on when fully conscious he has no memory of this period (antegrade amnesia), during which clinically he would be labelled conscious. In addition, memory for a varying period prior to injury may be wiped out (retrograde amnesia). It is interesting that full recovery is only achieved when the patient starts to record a memory trace of the ongoing activities. This transition, in a patient otherwise appearing to be fully conscious, is usually abrupt and easily discernible by an observant clinician. The progressive recruitment of neural substrates subserving reflex activity, speech, memory etc. is the obvious explanation for this behaviour.

The severely injured patients provided opportunity to study lesions of various sites, severity and nature resulting in disturbed consciousness. From amongst a consecutive series of 3000 cases of head injury, we selected 265 patients for a detailed clinico-pathological evaluation. This study not only provided some insight into the diagnostic and prognostic significance of post-traumatic unconsciousness but also initiated a quest for understanding its pathogenesis. Invaluable information was thus gathered to modify our management protocol resulting in improved outcome of our patients. From a more practical standpoint it became obvious that the most important single factor which is decisive for operative indication in a patient with closed head injury is the state of consciousness. As long as the consciousness continues to improve, irrespective of the findings of any other sophisticated investigation, one could safely wait. Failure to show continued, uninterrupted improvement, or any secondary deterioration should alert the surgeon about the need for surgery. However, this is not what is proposed to be discussed here, but those aspects of our studies (including those that followed over the years) which are of some relevance to our understanding of the phenomenon of consciousness.

Brainstem Dysfunction in Cranio-Cerebral Trauma (Tandon 1964) and *Clinico-Pathological Observations on Brainstem Dysfunction in Cranio-Cerebral Injuries* (Tandon & Kristiansen 1965)

From amongst 229 cases of severe head injury, 132 of whom proved fatal, 49 had brainstem

haemorrhages. Pathological studies confirmed that in cases of head injury primary (initial) and secondary (delayed) impairment of consciousness could be due to functional disturbance or structural damage to the brainstem. The important contribution of these studies was to establish that clinically or even with the help of the then available diagnostic techniques it was not possible to differentiate between those with functional disturbance, having a better prognosis and the ones with brainstem haemorrhages with generally fatal outcome. These studies also indicated that contrary to the prevailing belief, even cases belonging to the latter category could survive. This not only brought theoretical hope to those considered hopeless, but prompted us to persevere and not give up as hopeless the management of such patients. The validity of this approach has now been unequivocally confirmed by us.

Post-traumatic Brainstem Haemorrhage: A CT Study (Mahapatra et al. 1992)

In a recently completed study on 80 patients with CT verified brainstem haemorrhage (45 in mid brain and 35 in pons) in head injured patients we observed that atleast 5 had retained reasonable degree of consciousness (Glasgow Coma Scale 9), while 2 had never lost consciousness. Even though nearly one third of them had other associated lesions, 31% made good recovery, a few atleast as good as normal.

Cold Caloric Test in Altered States of Conscious-ness (Jadhav et al. 1971) and *Vestibulo-Ocular Reflex and Brain stem Lesions: A Clinico-pathological Study* (Tandon et al. 1973)

Recognising the fact that the anatomical substrate of the vestibulo-ocular reflex is located in the brainstem, the same region of the brain which plays an important role in maintenance of clinical consciousness, it was felt that a study of this reflex in unconscious patients may provide useful diagnostic and prognostic information. A detailed study of 75 patients with altered states of consciousness was conducted. This study was initiated at a time when hardly any information was available on the subject. It revealed that this simple bedside investigation could provide invaluable information, necessary for assessing the level of consciousness when such well accepted physical signs, like response to pain, pupillary reaction and corneal reflex, give conflicting results. In addition it was observed that repeated caloric testing provided a more reliable indication of the impending change, improvement or deterioration, in the level of consciousness than any other clinical sign.

Bilateral Decerebration in Head Injured Patients (Mahapatra et al. 1985) *and Brainstem Auditory Evoked Response and Vestibulo-ocular Reflex in Severe Head Injury Patients* (Mahapatra & Tandon 1987)

This was further confirmed in a group of very severely injured patients i.e. those presenting with decerebration (Glasgow Coma Scale of 4). This clinical picture strongly suggests involvement of the brainstem. Interestingly enough when a sophisticated electrophysiological test, auditory evoked potential, became available to study the functional integrity of the brainstem, a comparative study was carried out by us to evaluate the results of the two investigations. It revealed that the simple cold caloric test provided as good as, if not better, indication of the prognosis than the study of evoked potentials (Mahapatra & Tandon 1987).

Electroencephalographic Study of Sleep in Cases of Prolonged Unconsciousness (Tandon et al. 1972)

It is generally accepted that sleep is a depressed state of consciousness, yet sleep is not equivalent to unconsciousness or coma. Over the years the anatomical substrate responsible for or involved in the genesis of sleep has been elucidated (Jouvet 1967, Rossi 1963, Desiraju et al. 1967). The location of atleast a part of the anatomico-physiological substrate of sleep in the brainstem, where Moruzzi and Magoun (1949) had already identified the arousal system in the reticular formation, prompted us to study electrographic sleep in patients with prolonged unconsciousness, due to a variety of lesions of the brain. Knowing the well established electrographic features of sleep, we assessed the presence or absence of various phases of sleep in EEG and polygraphic records lasting 6-8 hours obtained from these patients. It was interesting to observe that fully formed electrographic patterns of various phases of sleep, indistinguishable from that seen in normal persons, were observed in some of these patients unconscious for days and even weeks. These observations would suggest that the neural substrate responsible for consciousness could not be identical to the one subserving sleep and wakefulness.

From these studies it is apparent that for most part we concentrated on brainstem mechanisms involved in maintenance or disturbance of consciousness. We were ofcourse conscious of the fact that consciousness is too important a human attribute to be assigned to a very restricted, small part of the brain. To give an example, a 32-year-old lady, following an head injury, developed an acute subdural hematoma and left temporal lobe contusion. The hematoma and the damaged temporal lobe were surgically evacuated. Following operation she was adjudged to be in mild coma. She remained in this state for a week when her conscious state started to deteriorate. She died 13 days after injury. At autopsy there was no residual hematoma. There was a post-operative cavity at the site of removed temporal lobe. The brain stem showed no macro or microscopic abnormality. Let me therefore enumerate just a few examples of patients in whom disturbance of consciousness, in somewhat broader sense, resulted from involvement of other parts of the brain.

Observations on other Groups of Patients with Impaired Consciousness

A variety of systemic insults, hypoxia, hypotension, hypoglycaemia, toxaemia etc. result in unconsciousness in absence of any clinical or pathological evidence of brainstem abnormality. On the other hand, there is ample evidence of diffuse cortical damage in these patients.

Anoxic brain damage : A 30-year-old male was admitted to our service following an attempted suicide by hanging. At the time of his admission to the hospital he was deeply comatose, though his vital signs were well maintained. He had marks of strangulation on his neck. He died 7 days later without regaining consciousness. At autopsy his brain was found to be swollen and edematous. He had obviously sufferred anoxic damage to the brain, as confirmed by histological studies of the cerebral cortex. However, there was no macroscopic or microscopic abnormality detected in the brainstem.

Epileptic automatism : On the other extreme are cases of automatism secondary to focal epileptic discharges in the frontal or temporal cortex. During such attacks a patient is not only capable of carrying on the ongoing activity he was involved in but also execute complex

coordinated acts without being aware (conscious) of these either during or after the attack. There is enough electrophysiological evidence to establish that during such attacks the abnormal discharge originates in the cerebral cortex, while the brainstem mechanisms mentioned above are not involved.

Global amnesia : One could include in the same category patients who suffer attacks of global amnesia wherein a person in full possession of all his mental faculties suddenly loses his memory, either due to a transitory fall in blood sugar or blood supply to the brain. A distinguished professor addressing a conference, all of a sudden started to fumble with his papers, looked around blankly, had to abruptly end his talk in the middle. When questioned he said he was alright, nothing is the matter with him. On recovery from the episode, he could recount everything upto the time he was normal but nothing of what transpired during the half an hour of the episode of amnesia. During this time, he walked to a chair, kept on talking irrelevently, though occasionally responding correctly to simple questions and commands, drank a glass of juice offered to him. Could he be called conscious during the period when for all practical purposes he acted as an "automaton"?

Korsakoff psychosis (Amnestic confabulatory syndrome) : Classically this condition is seen in cases of chronic alcoholism as a result of a damage to the mamillary body. An identical condition has, ofcourse, been encountered in other conditions including head injury. The patient for all practical purposes is alert, awake, retains full capacity to respond to external stimuli and even hold conversation. It is the content of his conversation that gives away the underlying deficit. When talked to he is prompt to reply but what he says though linguistically correct lacks insight, not based on the contents of his memory, but as spontaneous ad-lib repartie, for which the patient has no recollection even few minutes later. To give an example one such patient when greeted by the examiner responded with such enthusiasm as if he is meeting a long-lost friend. When asked if he knew the examiner he said "ofcourse I do. Haven't we known each other for years". On being further questioned about the examiner's identity, he jokingly avoided the answer by stating, "Old friends don't ask such questions" and promptly offered a seat and asked "how about a drink", even though he was sitting in a bed in the general ward which he acknowledged when this was pointed out to him without manifesting any embarrassment. A lot more such casual conversation was held, however 15-20 minutes later when the examiner returned and enquired as to when they had met last, without any reduction in bonhomie, he had no recollection of the earlier encounter with the examiner. Sounds quite like the "Cocktail Party Syndrome"! Nevertheless few days later when he had fully recovered from the effect of this trauma, he behaved like a cultured, informed, rational person.

In contrast to these one could present a number of examples with gross structural lesions of the brainstem without impairment of consciousness.

Locked-in syndrome : In this condition usually due to a vascular damage to the upper brain stem the patient loses voluntary control of all his body, except some limited movements of the eyes. This is mistaken for unconsciousness. Yet a careful examiner could detect the movements of the eyes and establish remarkable contact with the patient who is instructed to reply to the questions in "Yes" or "No" by moving his eyes as per an agreed code. Such patients retain full memory for the

period they remain in this state. Unwary physicians, considering the patient unconscious, may make some remarks not meant for the patient, whose verbatim recall of the event at a later date may be a source of embarrassment to the physician.

Brainstem tumors : Patients with very large tumors, involving at times virtually the whole of the brainstem, retain full consciousness even at a stage when they have lost practically all power to move their limbs (quadriplegia) or even eyes (ophthalmoplegia) voluntarily. In addition they may virtually lose their ability to speak (due to anarthria or aphonia), or swallow their own saliva. Notwithstanding all these disabilities, with patience and gentle care one could demonstrate their awareness of self and surrounding (the clinical hall marks of consciousness). Permit me to share with you our experience with one such patient-a poignant and pathetic example of such an affliction. This young, well built, handsome engineering student, the only son of his parents, studying in USA, developed progressive symptoms of brainstem involvement. On a mistaken diagnosis of tumor outside the brainstem he was submitted to surgery. No tumor was found. Continuing to deteriorate, he was flown back to India. When we first saw him, he was confined to bed, virtually paralysed from neck downwards. In addition he had marked impairment of hearing and loss of function of number of other cranial nerves. His speech was incomprehensible due to gross dysarthria. Investigations confirmed that he had an intrinsic tumor of the brainstem which was considered inoperable. His condition continued to deteriorate relentlessly, the paralysis became dense, requiring intermittent artificial ventilatory support. No audible speech could be heard, he could not clean his throat, nor drive away a fly irritating him on his face. Yet, at times he appeared fully awake and conscious, looking around. There was unequivocal evidence that he recognized his mother, emotionally responded to her gentle caressing and whispered words. None of the members of the medical team could communicate with him, yet nearly till his end the brave and understanding mother could, though with difficulty, make him respond by gestures and flicker of the facial muscles, which only she could decipher with remarkable accuracy. Who could say that he was not conscious! At autopsy a large part of the brainstem was replaced by a tuberculoma.

Drawing upon a vast amount of clinical material, it would be easy to quote cases where some of the psychic components of consciousness are selectively affected by well defined lesions in the cerebral hemispheres. A variety of agnosias and apraxias are commonly observed in patients with lesions in the parieto-temporal cortex. "Word blindness", "word deafness", "visual agnosia", "inability to recognise faces", "dressing apraxia", "gait apraxia", are well known clinical entities. Thus a fully literate person, without any defect in his vision, may not be able to read or understand what is presented to him in writing, yet fully comprehend the same when read out to him. In other words he has lost "perception" of the written words (visual agnosia). The reverse is true for cases of "word deafness", who fail to comprehend spoken words but fully understand the same presented in writing. In contrast to these are patients who in full possession of understanding and normal voluntary control over the muscles are unable to execute ordinary acts like walking (gait apraxia) or putting on their dress (dressing apraxia) as a result of a circumscribed lesion in the parietal lobe. Since awareness of

self is considered an important component of consciousness, it may be of interest to know that such lesions can result in denial of one's own opposite half of the body. Likewise a patient with normal vision and visual field when simultaneously presented with stimuli on both sides, may consistently show lack of awareness of the stimulus on the side opposite to the damaged parietal lobe. Patients with bilateral lesions of the occipital lobe, who obviously are blind, deny their blindness though they can not perceive even light. On the other hand are examples of patients with amputations who continue to feel the existence of the limb that is no more there (the phantom limb). This perception then is not dependent on sensory stimuli emenating from the limb itself and travelling along the known sensory pathways to the brain.

Quite apart from such patients with impairment of specific perceptual faculties are those with impairment of more complex behavioural components of consciousness. Apathy, lack of drive, socially inappropriate behaviour are common features of medial frontal lobe lesions, while disturbances of emotion and memory are frequently seen in lesions of the temporal lobe. Unprovoked laughter, not associated with feeling of mirth, is seen in cases of pre-pontine tumors, while emotional incontinance, spontaneous laughing or crying, is a feature of pseudobulbar palsy or bilateral pyramidal tract damage in the brain. Unexplained unprovoked 'bursts of temper-tantrum", "aggressive episodes", even "nymphomania" have been recorded in patients with focal lesions of the brain. "Mystic experiences" have been attributed to temporal lobe epilepsy (Desai 1968, Dewhurst & Beard 1970).

It will thus be obvious from the case studies and individual examples cited above that whether it is the "crude" consciousness that neurosurgeons evaluate in their patients every day or "the awareness of self, and environment", or the two components psychologists talk about i.e. vigilance and psychological or the Schrodinger's (1967) all encompassing "knowing, feeling or willing" mind, any component or the whole of it can be disturbed by specific functional or structural alterations of the brain or well defined parts of it. It may be observed that I have not even talked about chemical means of achieving the same. There is vast literature on the effect of narcotics, psychotropic and hallucinogenic drugs which could alter consciousness through their action on the brain.

All this information would prompt an unwary clinician to proclaim that we know all that is to be known about consciousness brain-mind relationship. Alas, the reality is different, more complex and we still are far from a satisfactory resolution of the problem as will be obvious from the discussion that follows.

Discussion

Definition of Consciousness

The most difficult task concerning the subject voiced by one and all is in respect to finding a suitable definition of consciousness. Chamber's Everyday Dictionary defines consciousness as the totality of mental states and processes (perceptions, feelings, thoughts): mind in its widest sense, awareness: the waking state of mind. It defines mind as faculty by which we think, the whole spiritual nature, memory, intention, inclination, casts of thought and feeling. Specialists belonging to diverse disciplines mentioned earlier have not only failed to find a generally acceptable definition, but have interchangeably used terms like mind, consciousness, psyche, soul and spirit etc. Some

have considered these terms as synonymous, others have alluded to one being part of the other. The following examples will amply testify to this confusion. The persons quoted below represent some of the most outstanding brains known to civilization, therefore, their inability to provide a commonly acceptable definition, reflects the inherent complexity of the problem.

Exactly one hundred years ago, William James (1892), the father of American psychology said, "consciousness is not a thing but a process". He added that everyone knows what consciousness is until he tries to define it.

And as recently as 1957 Lindsley, stated there was very little agreement on a definition of consciousness and in the end the conclusion was that each person had his own concept of it. He emphasized the importance of sensory or perceptual discrimination which in turn may be measured in terms of the nature and intensity of the stimulus necessary to bring it about.

Stanley Cobb concluded (1952), "It is the integration itself, the relationship of one functioning part with another, which is mind and which causes the phenomenon of consciousness". This is also echoed by Kristiansen. The term consciousness includes a series of different elements in incessantly changing relation. These changing patterns of mental activity may be described with reference to their contents of sensation, perception, attention, memory and volition (Kristiansen 1964).

Sperry (1966) often uses the term "conscious mental forces", while Popper and Eccles (1977) use the expression 'self-conscious mind" which according to them is something utterly different from any thing which has previously existed in the world.

Schrödinger (1967) felt that "consciousness is in many ways still a prescientific concept with multiple inconsistent meanings. Included are such disparate elements as perception, attention, volition, self-awareness and memory". At another place he states, "Mind has three aspects i.e. knowing, feeling and willing". He repeatedly uses the term consciousness and mind interchangeably.

Campbell (1980) concluded, "Consciousness is not identical with the brain or mind, but is that which witnesses changes which occur in brain and mind."

"Mind is often equated with consciousness, a subjective sense of awareness" Fischbach (1992). Furthermore he states, "there is more to mind than consciousness or the cerebral cortex."

Carla Shatz (1992) talking about the intricate network of neurons proposes that it is their connectivity "that makes possible memory, vision, learning, thought, consciousness and other properties of the mind."

Moving to a more philosophical plane, Vedanta proclaims, "BRAHMAN is EXISTENCE itself, Consciousness". And

> *"in depths of meditation there arises the consciousness of the impartite, the indivisible Reality. Body is forgotten, mind ceases to function-there remains pure CONSCIOUSNESS."*
>
> *as experienced by Sri Ramakrishna*

Seshachar (1983) who while expressing the difficulty of fully defining consciousness talked of three levels, (a) knowledge and awareness of the external world by extroceptors, organs of sight, hearing etc., (b) Innersensing, not directly derived from sensory data but triggered by them; e.g. emotions, intentions, imagination,

and (c) knowledge of one's self (other than the body) characterised by the recognition of the present from the information of the past, and a projection of the future, providing a continuity in one's life time. The belief that there is an 'I', the self, who does the perceiving in man, makes possible the creation of the ethical, aesthetic and spiritual values regarded as unique to man.

What Constitutes Consciousness

Not being able to define, let us consider as to what constitutes Consciousness? Awareness, attention, cognition, discrimination, memory, responsiveness, volition etc. are atleast some of the definable constitutents of the unitary state of consciousness. Since these could be quantified to a lesser or greater extent, these lend themselves to scientific investigations. Voluminous literature has, not surprisingly, accumulated on these aspects of consciousness. These need not be and cannot be discussed here in detail. Nevertheless since these are of direct concern to the clinicians it may be interesting to very briefly consider these here. Sperry (1966) eloquently pointed out that "the inner sensations, feelings, precepts, concepts, mental images or the like cannot be dealt with objectively by any known scientific methodology". These, no doubt, essential components of our consciousness, have received attention from philosophers, saints and sages.

It is, however, important to recognize that individually none of the components amenable to empirical study could be equated with consciousness. Thus, even unicellular organisms are endowed with capability to sense the biologically significant stimuli in their environment and respond to these purposefully, yet no biologist will endow them with the dignity of possessing consciousness.

Sensory perception has been considered as an essential ingredient of consciousness. Yet the experiments of Hebb (1954) and others have demonstrated that consciousness can be maintained in the virtual absence of sensory input. One has seen several patients, deaf and blind due to bilateral acoustic tumors retaining full consciousness. Ofcourse it could be argued that they still had other somato-sensory inputs preserved. The "Yogis" burried underground for several days are known to have come out of their "hibernation" fully conscious.

Even the ability to discriminate the sensory stimuli as observed in more evolved animals like for example *Octopus*, which possesses a high level of visual and tactile discrimination, could not be called consciousness. In short mere possession of sensory-motor mechanisms, is not sufficient to demonstrate consciousness. Such mechanisms, with increasing degrees of complexity are observed as we climb up the evolutionary ladder without any evidence of consciousness. Likewise responses, including some complex behaviours, could be observed purely as reflex mechanism–simple or conditioned–without encroaching on the consciousness. One could similarly question the role of attention, perception and memory in the causation of subjective experiences of consciousness. While attention may be necessary for learning or registration of memory, it is obviously not an essential ingredient of consciousness. Can a small animal attentive to every move of its predator be called conscious?

Memory appears to play a more important role but memory alone could not be equated with consciousness otherwise the immune system which has a fantastic repertoire of memory or even an ordinary computer would be considered to posses consciousness. On the other hand patients with global amnesia, Korsakoff

syndrome, Alzheimer's disease etc. mentioned earlier would be declared unconscious. William James (1892) thought that consciousness involved both attention and short term memory. Yet Kendel and Hawkins (1992) are reported to have concluded from their studies on brain-damaged patients that the ability to lay down new long term episodic memories is not essential for consciousness. Crick and Koch (1992) however felt, "It is difficult to imagine that anyone could be conscious, if he or she had no memory whatsoever of what had just happened, even an extremely short one." Experience with head injured patients, soon after concussion, who are clinically considered conscious, yet have a variable period of total amnesia would, nevertheless, argue against such a belief. Popper (1977) stated, "There can be very little doubt that memory is essentially physiological and brain-based. There can also be little doubt that, like general brain activity, memory is one of the pre-requisites of consciousness."

It is, therefore, obvious that collectively a variety of psycho-physiological factors are responsible for maintenance of full consciousness, singly none of these could account for it nor be equated with it.

States of consciousness : Hughlings Jackson (1931) an astute neurologist commented "consciousness is a varying quantity, that is, we are from moment to moment differently conscious." In day to day life the obvious states of consciousness are awake and sleep, to which one may add drowsiness. In the ordinary clinical jargon one uses terms like stupor, semi-conscious, unconscious or comatose. A numerical quantifiable classification, called the "Glasgow Coma Scale", was hailed as a major contribution to clinical neurology. To this the psychologists added terms like sub-conscious and ego etc. For day to day clinical practice such classifications, no doubt, are very useful, however, these fail to communicate the actual complexity of the subject. It is, therefore, tempting to search for the wisdom of the basic scientists, the thinkers and the philosophers.

Upanishad and Vedas are the earliest sources that I could trace. There is a wealth of knowledge there, unfortunately not easily accessible for those like me without a good grasp of Sanskrit. I have, however, been able to obtain some glimpses through the writings of other scholars. (Neki 1983, Campbell 1980, Kothari 1980, Gandhi 1983, Vivekanand 1958, Sri Aurobindo 1968, 1970).

In its simplest form Mandukopanisad describes only four states of conciousness-jagriti (awake), swapna (dreaming), susupti (deep sleep) and turiya (non-dual consciousness). The Taittiriyo-panishad classifies consciousness at an entirely different plane: the physical consciousness (anna-mayakosa), the psychic consiousness (manomayakosa), the intuitive consciousness (vijnana mayakosa) and the beautitudinous consciousness (ananda-mayakosa).

The Upanishads maintain that consciousness evolves in each individual from the physical plane to the vital, and from vital to the mental at which plane most of humanity lives. Some individuals, however are able to rise above the mental plane of creative intelligence (budhi) and then that of bliss (ananda).

In addition one finds treatises discussing the subconscious, the transcendental consciousness, the mystic consciousness, spiritual consciousness and God consciousness. This inspite of the fact that the Advaita Vedanta repeatedly emphasises that "the consciousness is one", omnipotent and omnipresent. No doubt it

also talks of different planes including creative intelligence (Budhi) and the ultimate consciousness or the bliss (Ananda).

In Charak's expositions one finds a number of references dealing with the subject (Ray & Gupta 1965). Living things are composed of the five *mahabhutas* and three other constituents: avyakta (atman or unmanifest self), *budhi* (intelligence) and *ahmkara* (ego). The ego is made up of action, the consequences of action, reincarnation and memory, and is independent of the physical body. It can exist without the latter (Sa 1, 63). The five *mahabhutas*, together with spirit, mind, time and space constitute the totality of all substances (Sv 1, 48). They are perceptible to the senses or to the mind (Sv 1, 62).

All senses are mere variations of the *mahabhutas*, but each sense partakes of one *mahabhuta* in a prepondering degree and possesses special capacity for grasping that particular *mahabhuta* (Su 8, 14).

Conscious perception arises from the fusion, of the *atman*, mind, senses and sense objects (Sa 1, 34). This fusion cannot be achieved by accident, an agent is necessary (Sa 1, 44). The ultimate source of consciousness and knowledge is the *Purusa* or transcendent self (Sa 1, 41). The *Purusa* has no beginning in time, it is not manifest to the senses, cannot be realised except by inference and does not come under any known category (Sa 1, 60 & 62). It is everlasting, all-pervading and changeless (Sa 1, 61). Had there been no *Purusa* there would have been neither good nor evil, no knowledge, no doer and no knower (Sa 1, 39). All these could be causeless. Neither could there be any awareness of these, nor would they serve any purpose of their existence (Sa 1, 42). There would have been no dissolution nor creation, no birth nor death, no continuity of life, no consciousness nor perception, no pleasure or pain, no dynamic nor static condition, no science nor scripture, no bondage, no liberation, if there was no *Purusa* (Sa 1, 38-41).

Charak holds that life results from a combination of the body, the senses, the mind and the self *(atman)*, and that it rests on the body, the mind and the self, as on a tripod.

Anuruddha, a Buddisht monk, in a treatise Abhidhammathasangha, describes 52 different modalities of consciousness in which seven are considered universal, impression phases (both contact and impact), feeling *(Vedana)*, perception *(Sanna)*, Volition *(Sankhara)*, focussed attention *(Manasikara)*. In addition he mentions enquiry *(Vitakka)*, investigation *(Vicara)*, decision *(adhimonkkha)*, effort *(viriya)*, interest *(piti)* and intention *(chanda)*.

It is interesting that even in recent times, scientists and philosophers talk of such states often with different connotations. Freud popularised the concept of sub-conscious mind as a determinant of human psyche and behaviour. Maharisi Mahesh Yogi not only made transcendental meditation a buzz word in the West, but stimulated a lot of scientists to investigate this state scientifically (Allison 1970, Wallace 1970, Gellhorn & Kiely 1972).

All cultures, Eastern, or Western, acknowledge the occurrence of 'mystic' experience recorded by some rare individuals. William James, in his Gifford Lectures, "Varieties of Religious Experience" gave an illuminating discussion of mystical experiences. C.J.Young, who has written a great deal on the subject concluded, "Religious experience is absolute. It is indisputable." And furthermore, "no matter what the world thinks about religious

experience, the one who has it possesses the great treasure of a thing that has provided him with a source of life, meaning and beauty and that has given a new splendour to the world and the mankind". Ofcourse, nearer home examples of such beliefs, nay convictions, are many, the most vividly described being the ones by Sri Ramakrishna, Sri Aurobindo. Gandhiji, no saint in the usual sense of the world claimed to have heard the "Voice of God". He affirmed that "I can say this that not the unanimous verdict of the whole world against me could not shake me from the belief that what I heard was the Voice of God... For the voice was more real than my existence." Campbell, as recently as 1980, once again reverts to the concept of seven states of consciousness in his book with that title.

Neurobiological Studies

Irrespective of this array of definitions, states and contents of consciousness, let us revert to the knowledge gained through neurobiological, neurophysiological, molecular biological studies, to search for an explanation of what was observed in our patients and anything beyond it.

The Brainstem

The clinical cases referred to above unequivocally establish that functional or structural disturbances of a number of regions of the brain could alter or abolish consciousness or its constituents (perception, memory, emotion, volition etc.). Thus our studies on head injured patients strongly support the idea of brainstem mechanisms playing a dominant role. A small lesion in a critical location in the brainstem or its acute compression as in tentorial herniation secondary to supratentorial tumors, results in sudden loss of consciousness. Clinically it is so common to observe a fully conscious person, talking, thinking and behaving normally, lose consciousness in matters of minutes or even seconds as a result of sudden compression or displacement of the brainstem (transtentorial herniation). These observations alongwith other experimental evidence, suggested an important role for the brainstem reticular formation in maintenance of consciousness. However, more critical studies provided conflicting information. Thus absence of any disturbance of consciousness in patients with intrinsic large tumors of the brainstem or those grossly distorting it from outside (Kristiansen 1964), preservation of normal or near normal consciousness in patients with sizeable haemorrhagic or ischaemic lesions of the pons and medulla (Paillas et al. 1964), inability to produce unconsciousness by injection of sodium amytal (a neuroparalytic agent) in the vertebral arteries supplying the brainstem (Alema & Rosadini 1964), and above all occurrence of coma in a variety of lesions without evidence of brainstem involvement would imply that brainstem though important is not the only structure responsible for maintenance of consciousness, even in the restricted sense the clinician use. Brodal (1964), who contributed a great deal to the anatomical studies of the reticular formation (RF) ultimately concluded, "In so far as anatomical features may serve as clues to an understanding of the functions of the brain, the outcome of this discussion must be that many other parts of the brain than the RF must be related to consciousness... and to consider this, like so many other functions, as being more or less dependent on the whole brain."

The Diencephalon

Fulton and Bailey's (1929) description of a state of pathological sleep due to tumors in the region of the third ventricle drew attention to the role of diencephalon in relation to consciousness. Cairn and his associates (1941) observed

"akinetic mutism", a clinical condition in which the patient though "apparently" awake has no conscious awareness or volitional activity, in cases with lesions involving the diencephalon. Based on his critical studies of epileptic patients, Penfield (1958, 1969) located his hypothetical "centrencephalon" in this region. Discussing the pathogenesis of disturbances of consciousness associated with epileptic seizures, Penfield (1957) concluded, "when a man is conscious, neuron activity in higher brainstem and hemispheres continues in an ever-changing pattern. It is the organization of this activity that must form the basis of each successive conscious state. There can be no final organization, and no consciousness, without centrencephalic integration". This found support in Jasper's (1949) experimental studies on the integrative action of the thalamic reticular system. Dott (1960) attributed the loss of consciousness secondary to displacement of the brain, to be due to ischaemia of the diencephalon.

Cerebral Hemispheres

Surgical removal of one hemisphere and for that matter large parts of both hemispheres, or removal of any of its lobes, does not result in loss of consciousness. For obvious reasons results of removal of both hemispheres are not available. Could then one presume that cerebral hemispheres are not involved in maintenance of consciousness? On the basis of their investigations on patients following intracarotid sodium amylobarbitone, Serafetinides et al. (1965) observed that loss of consciousness resulted invariably when the hemisphere dominant for speech was injected, which was rare and of a comparatively short duration following injection of the non-dominant hemisphere. These findings, though contradicted by Rosadini and Rossi (1967) suggested the possibility of atleast some role of the dominant hemisphere (the left in right handed persons) in relation to consciousness. This finds some support form studies on the split brain.

Sperry and his colleagues in a series of ingenious studies on patients whose two hemispheres were separated surgically by commisurotomy for treatment of intractable epilepsy, observed that, "the two hemispheres appear to be independently and often simultaneous conscious, each quite oblivious of the mental experience of the opposite hemisphere and also of the incompleteness of its own awareness" (Sperry 1968, 1970a, 1970b, Sperry et al. 1969, Trevarthen & Sperry 1973). The unity of self consciousness or the mental singleness that the patient experienced before operation was retained, but at the expense of unconsciousness of all happenings in the non-dominant (minor) hemisphere. Thus the patient was unaware of the stimuli presented to the right hemisphere of a right handed person, even though unequivocal evidence could be established that this minor hemisphere (i.e. the right) continues to perform as an intelligent brain with refined abilities of stereognosis, pattern recognition and copying etc. This would imply that in normal persons activities in the minor hemisphere reach consciousness only after transmission to the dominant hemisphere. Popper and Eccles (1977) have therefore postulated that "self-consciousness is derived only from neural activities in the dominant hemisphere" (see later).

Another unique observation was made by Dr Penfield. During surgery for epilepsy on conscious patients under local anaesthesia gentle electrical stimulation in some of them activated the past record of the "stream of consciousness." Limited to the duration of electrical stimulation, the patient "re-lived" all that he had been aware of in that earlier experience, a record of which was laid down initially. To quote Penfield &

Perot (1963), "The conclusion is inescapable that some, if not all, of these evoked responses represent activation of a neural mechanism that keep record of current experience. There is activation too of the emotional tone or feeling that belonged to the original experience. The responses have that basic element of reference to the past that one associates with memory. But their vividness or wealth of detail and the sense of immediacy that goes with them serves to set them apart from the ordinary process of recollection which rarely displays such qualities". It is interesting that all these patients even during the time they were having the experiential response retained full awareness of the operating room and of events occurring in it. Just to give one example, a young South African patient lying on the operating table on stimulation of his temporal cortex exclaimed that it was astonishing to realize that he was laughing with his cousins on a farm in South Africa, while he was also fully conscious of being in the operating room in Montreal. It was observed that if stimulation was maintained for a time, the action or the normal course of events in an experience progressed at a normal rate and ceased upon withdrawl of the stimulus. The evolving detail was far greater than in memories which can be summoned voluntarily. Such responses were obtained only form the temporal lobe and more specifically from that region designated by Dr Penfield as "the interpretive cortex". He concluded that "This demonstrate the existence of a functional system devoted to subconscious recall of past experience and to the interpretation of present experience".

As mentioned earlier memory is an important constituent of consciousness. It may, therefore, not be out of place to describe a patient of ours.

A 54-year-old male during vertebral angiography on 7.5.1974 for investigation for a brain tumor suddenly developed a momentary lapse of consciousness and blindness. He remained confused though conscious, and without any neurological deficit except blindness, from 8.5.1974 till 9.30 AM - 11th May 1974, when he recovered his vision. However, disorientation in time, place and person persisted, while he could correctly tell about the events of the past. Twenty four hours later it could be established beyond doubt that he was suffering from gross defect of recent memory. He was unable to tell the date. When told that the examiner had informed him the date the day before and warned him at that time that he will ask again, the patient replied that, "to be honest I don't even remember your visiting me yesterday". He could not recall what he had eaten a little while earlier, nor who all had visited him, though he could recognize his wife and brother present in the hospital room. Next day when asked about the examiner's name, he said that, "he had been told repeatedly since morning that your name is Dr Tandon. I, however, don't remember seeing or knowing you earlier". He could tell that Pakistan was created in 1947, but he was totally unaware of the existence of Bangla Desh. He could count correctly and do simple arithmetic 3+5=8+7=15 and 8x7=56. When last examined nearly a year later, his vision was normal, neurological deficit due to the 8th nerve tumor unchanged, but he had persistent defect in memory. During the examination he volunteered that he knows he is married but neither the date, nor the place of wedding, not even the year of his birth or joining of the service.

This sequela of vertebral angiography was obviously due to impairment of blood supply to the medial temporal lobe structures bilaterally. This finds support in the observations of Milner (1958), Penfield and Milner (1958) and Scoville & Correll (1973) on patients with bilateral lesions

of the hippocampus and hippocampal gyrus. Careful and repeated psychometeric evaluations of these patients led Milner (1958) to conclude that, "the capacity to record the daily current of conscious experience may be lost in such cases. This memory loss appeared in isolation from any disturbance of reasoning, attention or concentration. The observations were considered to have "thrown welcome light on the location of some portion atleast of the ganglionic record of current experience."

Mention has already been made about the effect of diffuse cortical neuronal damage secondary to head injury, hypoxia, hypoglycaemia, and other metabolic insults on consciousness. Such patients could survive for months and years maintaining all their vital functions, manifesting regular periods of sleep and wakefulness, yet showing no evidence of higher mental functions, perception or volition, leave aside speech, memory or emotions, Rowbotham (1964) suggested that "the cerebral cortex may often be the seat of consciousness". While not denying the role of brainstem he postulated that "basal and brainstem mechanisms can only be conscious when there is also some degree of cortical activity."

Thus on one extreme are people like Rowbotham (1964) who was "inclined to suggest that the whole of the ten thousands and million neurones of the brain must be in virtual continuous communication with each other. In simple terms each neuron in the central nervous system knows, at all times, what every other neurone is doing. In this conception.....no high centre is postulated for integration, the brain mechanisms concerting as a whole". On the other extreme, are those who postulate that the brain and the mind though not necessarily independent are quite separate entities and hence the latter has no anatomical substrate" (See later).

To this consideration of "space" was added a new dimension of "time" by Kristiansen (1964). While discussing the pathogenesis of unconsciousness in a variety of patients he commented, "A massive reduction of the amount of nervous tissue in regions considered important for the maintenance of consciousness is thus not sufficient to abolish the conscious state. The time factor seems to be a necessary component....."

Psychological, Psychobiological and Cognitive Studies

According to the behavioural scientists consciousness is a dual state composed of two factors: 1. the physiological component vigilance, which is necessary for the patient to be able to react, but is by itself insufficient to create consciousness and 2. the psychological component (Jefferson 1960, Paillas et al. 1964, Cazullo & Mancia 1964). Psychologists tended to talk of "crude consciousness" as identical to vigilance, and differentiated consciousness i.e. the capacity to analyze, to make synthesis, to recall experience and to integrate them in the Ego structure as "the consciousness." They considered consciousness as a complex of psychological processes which come to the subject in a certain time and allow him to become aware of himself and of his environment. Consciousness thus was a dynamic activity which makes us aware of our psychological life and of the possibility of integrating this awareness with our past experience and our environment. While perception became the foundation stone, attention, memory, emotion, ideation, judgement became essential for a complete integration of sensory experience. This has been beautifully summarized by Cazullo and Mancia (1964), "Vigilance is a 'nervous' function sustained by the activity of reticular formation of the brain. Consciousness - which is based on vigilance but is not identified with it is not

controlled by particular structures and functions; it is superior 'psychic' activity, owing to it the sensoperceptive stimuli, the affective, volitional and intellectual experience are integrated into a particular model of behaviour, which implies the awareness of self in that time and that place distinguished by the surrounding world".

Till recently the behavioural scientists were handicapped in their study of consciousness being solely dependent upon introceptive methodologies which defied empirical testing. This has been made possible by the availability of technologies like PET, MRI, SPECT and Magnetoencephalography which permit non-invasive methods of studying anatomy, physiology and chemistry of discrete regions of the brain in fully conscious, thinking and performing adult person. Thus some Cognitive Scientists, who combine chemistry, biology and psychology, currently tend to believe that the countless chemical and physical processes going on inside the brain-neurons firing, chemicals released and metabolised-all add up to create the complex functions we attribute to mind. Raichle (1992) summarized the current scenario stating that, "the modern imaging techniques which have become available in the last decade allow us for the first time to begin to assign anatomic specificity of the embodiment of mind, mind being limited to multiple parallel processes occurring in time, and the brain being the structure defined in space". It is not the place or purpose of the present communication to describe or discuss these in any detail. However, it may be of some interest to indicate the current direction and thinking in this evolving field of research.

Ingeniously designed experiments by the psychologists, both in animals and man, reveal that psychic phenomena like concepts, ideas, memory, attention, perception, judgement etc. can now be studied objectively and quantitatively. Furthermore, discrete areas of the brain involved in these functions begin to be identified. Thus Patricia Goldman - Rakic (1992) in her paper, "Working Memory and Mind", states that "within the past two decades, however, neuroscientists have made great advances in understanding the relation between cognitive processes and the anatomic organization of the brain. As a consequence, even global mental attributes such as thought and intentionality can now be meaningfully studied in the laboratory". To quote a few others, Petrides (1991) demonstrated for the first time, that the monitoring of one's own actions is critically dependent upon a specific part of the frontal cortex. Jeeves (1991) observed that there are highly cognitive systems in the brain, supporting a strong "localisationist view of brain organisation". Study of the visual system has provided voluminous data on neural basis of perception. Taking the example of face recognition, he quoted evidence to show that particular cells or columns of cells are dedicated to this function. Furthermore, certain columns of cells deal with the processing of the full face's appearance and others with different profile views, and yet others are earmarked for the processing of emotional expression in faces. Damasio and Damasio (1992) reported that a large set of neural structures serves to represent concepts; a smaller set forms words and sentences. Between the two lies a crucial layer of mediation. Taking a simple example of a coffee cup, he postulated that these concepts are stored in the brain in the form of 'dormant' records. When these records are reactivated they not only evoke visual and tactile representations of its shape, colour, texure and warmth, but also the smell and taste of coffee. "All these representations are recreated in separate brain regions, but their reconstruction occurs fairly simultaneously". We have no doubt

come a long way form simple sensory - motor localisation in brain, or even Sperry's epoch making studies on split brain, demonstrating that the perceptual experience of each hemisphere appears to remain outside the conscious awareness of the other (Sperry 1968, 1970). Yet all this still does not tell "how" and "by whom" this "recreation" is carried out. Could it be the 'Mind'?

Molecular Biology Studies

Recent developments in molecular biology, recombinant DNA technology, molecular genetics and biotechnology have opened up unprecedented opportunities for neuroscientists. Primarily molecular biology is concerned with identifying the molecules, and their genes responsible for interneural communications, neurotransmitters, modulators, peptides, hormones etc. and mechanisms underlying their synthesis, storage, release, their receptors, at the synaptic, sub-synaptic or channel levels. However, all this ultimately is to understand the functions of the brain like memory, learning, sensory perception, the constitudents of consciousness in its broader concept. The possibility to observe these messengers and their receptors non-invasively in the brain of awake, active, thinking, feeling human beings is no more a scientific fiction. Some information specially in respect to specific areas of the brain involved in thinking, recollecting or even planning for a voluntary act is already becoming available. However, it must be appreciated that these studies are carried out on conscious persons, hence do not throw light on the mechanism of consciousness. Of necessity these are restricted to specific tasks and that too of a brief duration. Thus they provide insight into the functioning of brain but not necessarily of the "mind", unless one presumes that the two are the same.

Studies by Computer Scientists

Current developments in Neurosciences and Computer science (including Artificial Intelligence and Neural Net Works) have benefitted both. Increasing use of computers in helping the former to understand the brain and its function, on the other hand neuroscience findings are increasingly being utilized by the computer scientist to develop an Intelligent Computer.

In the present milieu when scientists are actively engaged in creating "Artificial Intelligence", (AI), it may not be out of place to see if they have anything to contribute to the basic concepts of consciousness - brain - mind problem. These scientists are engaged in creating computers that can learn for themselves, generalize from particular examples, draw particular examples from general principles. Or computers that can evolve new solutions to problem they have never faced, even express a wish or satisfaction or throw temper tantrums. All such attempts at AI are generally based on the current knowledge about the working of the human mind. It has been remarked that men like Marvin - Minsky, Roger Schank, Yigal Arens, Larry Jackel & Richard Howard, Terry Sejonwski and host of others are trying "to give silicon a soul". There are some who believe that the neuron, electron and the chip, the triangle must interact for progress. Derek De Solla Price of Yale University expected AI to team up with the human brain to change the very pattern of human thought.

There is no doubt that even the existing generations of computers have a remarkable "memory". These have the capabilities to carry out calculations, more complex and faster than the human brain is capable of. Nevertheless Gerald Edelman of the Neurosciences Institute, The Rockfeller University, New York, whose

group have created the largest neural simulation todate using a super computer, however, expressed grave reservations about the prevalent 'machine functionalism' theory which treats brain as if it were a form of Touring machine. Architecturally speaking everyone knows that the neuronal connectivity in human brain is not only much too complex but also variable from moment to moment, which thus cannot be reproduced by the computer engineers whose basic requirements is that of a prespecified point to point wiring. Another minor complication results from the extraordinary variability of the nervous system, both in space (between individuals) and time (plasticity within individuals).

Francis Crick (1989) felt that the hope of understanding the computational properties of the brain with the help of computer algorithms for neural network have not materialised. He argued that the brain is different from a computer in almost every respect.

Evolutionary Concepts

In an universe that is estimated to be 20 billion years old, earth is considered to be 4.5 to 5 billion years old, while human beings in the present form evolved only 40,000 year ago (Wald 1964). It has been asked, as to when consciousness evolved in this cosmic time scale. There are those who strongly believe that consciousness as defined here is purely a human attribute, which would automatically imply that there was no consciousness prior to evolution of *Homosapiens*. Philosophically speaking this creates a dilemma, since it is believed that there can be no existence without it being perceived by the conscious mind.

Popper (1977) described the following stages in the evolution of universe starting from hydrogen and helium, the heavier elements (liquids and crystals), living organisms and calls these World 1 (the world of physical objects). It is interesting to note that he includes living organisms under this category. His World 2, is the world of subjective experiences, sentience (animal consciousness) and consciousness of self and death. And lastly World 3 which includes human language, theories of death and works of art and science (including technology), in other words an evolutionary state representing the world of the contents of thought and the products of human mind. I have quoted this because without this background information it may not be possible to understand the whole hypothesis of self-conscious mind jointly postulated by Popper and Eccles (1977).

Irrespective of the validity of such a classification it does point out that like rest of the living organisms even consciousness has evolved through various stages, the primordial life, the protoplasm, the various phylogenetic stages, to its present state of awareness of self and the external world, and its various dimensions, emotion, thought, intuition etc. in the human being. There are those who believe in universal consciousness or so called "panpsychism" psychism, while others who accept consciousness as entirely a human attribute. And yet others who believe that the ants and the wasps, leave aside higher mammals, are endowed with some kind of consciousness, though nobody can verify whether they have awareness of self. Be as it may, it does engender hope of further evolution of human consciousness itself.

Philosophical Hypotheses

All this inevitably leads us to look towards philosophers and seers in search for a synthesis of such diverse empirical information. In an audience, like this, I will primarily restrict myself

to scientist-philosophers. The plethora of books and papers published even during the last decade on the subject of brain-mind-self and consciousness, by scientists from variety of disciplines other than neurobiology, include the molecular biologists, physicists, mathematicians, computer scientists etc. This is simply beyond the comprehension of a professional neuro-surgeon. Nevertheless a glimpse into this vast repository of wisdom will not be out of place. An attempt is made to seek answers to a few basic questions in these writings.

Is consciousness the function of brain?

If so, does it have a seat in the brain (localisation)

Can brain mechanisms explain consciousness in its entirety?

Are consciousness and mind synonymous?

What is mind?

Is brain the organ of mind?

These questions have been discussed through antiquity by philosophers and religious leaders of all convictions. Upanishads provide a fountain head of such knowledge frequently referred to even by Western Scientists like Schrödinger, Capra, Campbell etc. The Greek philosopher Plato favoured the notion of psycho-physical dualism, while Aristotle in his treatise "On the Soul" held that all souls are forms or patterns of living bodies. Hippocrates recognised the role of brain in mental activity. He proclaimed, "Men ought to know that from the brain and from the brain only arise our pleasures, joys, laughter and tears. Through it in particular we think, see, hear and distinguish the ugly from the beautiful, the bad from the good, the pleasant from the unpleasant". During Renaissance Descartes dominated the thinking with his extremely mechanistic approach to nature as a whole. He considered the body and the soul as two distinct entities. And he went so far as to localize the point of interaction between the soul and the body to the pineal gland. The traditional philosophies of mind (and consciousness) can be divided into two broad categories: dualist theories and materialist (or monist). The adherents of these two are further sub-divided into behaviorists, functionalists, mentalists, panpsychists and the believers of socalled "emergent" hypothesis. It is not the place or purpose to discuss these here. Those interested in these historical concepts will find a comprehensive review in the book by Popper & Eccles, "The Self and its Brain". Nevertheless, an attempt is made to briefly refer to the views of some of these scientist-philosophers.

Hughlings Jackson (1931), one of the most respected neurologists, proposed three alternatives for the relation of consciousness to activities of the brain. For him consciousness had a wide meaning including highest mental states. However, to avoid any confusion of implying that there is a seat of consciousness in the brain, he clarified, "We spoke of the substrata of consciousness being the highest nervous arrangement. Yet.....we do not really suppose there to be one fixed seat of consciousness". Sir Charles Symonds (1975) an ardent admirer of Jackson clarified that in writings of Hughlings Jackson "there is insistence on separation of consciousness, which is immaterial, from nervous arrangements, which are physical". Symonds (1975) himself, influenced by Sherrington and Stanley Cobb, favoured the view that consciousness was "a function of the brain in action". He further postulated that "It is a function, presumably, of synaptic activity, now here and now there". He thus considered himself a monist and mentioned that Russell Brain, "originally a dualist, became converted to what he called a neutral monism". Sir Charles Sherrington, an out-standing Neurophysiologist

of the century, who in 1933 wrote his famous book "The Brain and its Mechanisms" and in 1953, "Man on his Nature", said of Mind, "it is not a thing" i.e. it does not have a physical basis. In 1933, he stated, "we have to regard the relation of mind to brain as still not merely unsolved but still devoid of a basis for its very beginning". In 1953, he reiterated, "Mind, for anything perception can compass, goes therefore in our spatial world more ghostly than a ghost. Invisible, intangible, it is thing not even of outline, it is not a thing. It remains without sensual confirmation and remains without forever" (Note the similarity with some of the writings in the Upanishads).

Waddington (1961) in his book, "The Nature of Life" remarked, 'We confront in the problem of self-awareness a basic mystery..... we can explain to ourselves some of the mechanisms by which, for instance, light waves emitted from an object are focussed on our retina, and these electrical disturbances which travel into and around our brains. But the most essential step in the whole process is that these events cause us to be aware of something..... the nature of self-awareness completely resists our understanding."

Sperry (1952) echoes the same dilemma, "When we proceed to the question of exactly how conscious meaning is related to the spatio-temporal patterning of brain excitation", (resulting from various sensory inputs) "all certainty is lost and we enter an area of free speculation." In 1966, he most graphically summarised the prevalent view amongst brain scientists thus, "some 99.9 percent of those of us who work in brain research have held firmly during the past fifty years to the conviction that conscious mental forces have no place in any explanatory model or theory of brain function. The inner sensations, feelings, percepts, concepts, mental images and the like cannot be weighed or measured, photographed, spectrographed or chromatographed or otherwise recorded or dealt with objectively by any known scientific methodology" (Note that atleast some of it is currently being studied objectively). Furthermore, "Science can see the brain as a complex electrochemical communications net work full of nerve excitations, all governed by respectable scientific laws of biophysics, biochemistry and physiology, but few investigators, none that I know, have been ready to interject into this causal machinery of any mental or conscious forces". However, Sperry then goes ahead to propose a hypothesis wherein he stipulated that the conscious phenomena of subjective experience do interact with the brain process exerting an active causal influence, implying thereby that consciousness has a directive role in determining the flow pattern of cerebral excitation. He therefore believed that conscious awareness is "a dynamic emergent property of cerebral excitation" inseparabely tied to material brain process with all its structural and physiological constraints. However, no attempt is made by him to explain how, violating all rules of physics, the "emergent conscious awareness", determines "the flow pattern of cerebral excitation". It ofcourse does not prevent him from claiming that his hypothesis, "would put the conscious mind back into the brain of objective science and in a position of top command. It would eliminate the old dualistic confusions, dichotomies, and paradoxes, proposing instead a single unified system extending from the subnuclear forces near the bottom up through ideas at top". I must confess these beautiful statements coming from a Nobel Laureate, fail to answer the question, we are faced with. Ofcourse, hypotheses are not meant to answer questions but only provide a framework for future research !

A somewhat similar hypotheses is put forward by Popper and Eccles (1977), To quote Eccles, "Thus it is shown that the relationship between the mind and the brain is not something instantaneous and automatic as in a parallelistic theory. It involves a whole process of slow and gradual modification and of sculpturing, you might say with backwards and forwards interaction". This "forward and backward interaction" is carried out by what they designated the 'self-conscious mind'. Talking about the "self-conscious mind" itself, Eccles at one place states, "It is something utterly different from any thing, which to our knowledge, has previously existed". Even though all this is not easy to comprehend by an ordinary clinician, and yet emerging as it is, from discussions between one of the most outstanding philosopher (Popper) and the other a most distinguished neurophysiologist (Eccles) of our time, I take the liberty to quote a rather lengthy passage from their book, "The Self and its Brain", and leave it to the individual readers of this essay to assess its meaning and significance himself or herself."

"The self-conscious mind is actively engaged in reading out from the multitudes of active centres at the highest level of brain activity, namely the liaison areas of the dominant cerebral hemisphere. The self-conscious mind selects from these centres according to attention, and from moment to moment, integrates its selection to give unity even to the most transient experiences. Furthermore, the self-conscious mind acts upon these neural centres modifying the dynamic spatio-temporal pattern of neural events. Thus we propose that the self conscious mind exercises a superior interpretative and controlling role upon the neural events."

"A key component of the hypothesis is that the unity of conscious experience is provided by the self-conscious mind and not by the neural machinery of the liaison areas of the cerebral hemisphere. Hitherto it has been impossible to develop any neurophysiological theory that explains how a diversity of brain event comes to be synthesized so that there is a unified conscious experience of a global or gestalt character. The brain events remain disparate, being essentially the individual actions of countless neurones that are built into complex circuits and so participate in the spatio-temporal patterns of activity. This is the case even for the most specialized neurones so far detected, the feature-detection neurones of the infero-temporal lobe of the primates. Our present hypothesis regards the neuronal machinery as a multiplex of radiating and receiving structures-the experienced unity comes, not from a neurophysiological synthesis, but from the proposed integrating character of the self-conscious mind."

To revert to Sherrington (1953) may not be out of place, who in his book, "Man on his Nature" states the following:

"Strong contrast offers the success which has attended analytic study of the perceptible and which has attended analytic study of the percipient. The former has proposed the feeling, conation, and activity no doubt, but with what if any relation to electrical potential, heat and chemistry. For myself, what little I know of the how of one does not, speaking personally, even begin to help me towards the how of the other. The two for all I can do remain refractorily apart. They seem to me disparate not mutually convertible; untranslatable the one into the other". And further on; "How can a reaction in the brain condition a reaction in mind, yet what have we sense organs for, if not for that? This difficulty with sense is the same difficulty, from the converse side as besets the problem

of the mind as influencing our motor acts. I would submit that we to accept the correlation and to view it as interaction, body-mind".

Fodor (1981) pointed out the chief drawback of dualism to be its failure to account for mental causation. If mind is non-physical, it has no position in physical space, it therefore cannot give rise to physical effects i.e. brain activity without violating the laws of the conservation of mass, energy and momentum. He suggested that most philosophers now agree that no agreement has successfully demonstrated why mind body causation should not be regarded as a species of physical causation.

Bunge (1977) a philosopher from Montreal found psychoneural dualism unclear, at variance with the general framework of science and untestable. He favoured a monistic hypothesis called emergent materialism as his choice. However, he emphasized that this was still a programmatic hypothesis, in search of detailed theories, in particular mathematical ones.

It would appear that after all the insights provided by these thinkers, we have not been able to resolve convincingly the competing hypothesis of mind-body problem: psychoneural monism and psychoneural dualism. Bunge (1977) further subdivides the believers of each group into five subgroups. Evidence and logic has been provided in favour of each. He in the end favours a monistic hypothesis i.e "one can hold that the mind is not a thing composed of lower level things-let alone a thing composed of no things whatever-but a collection of functions of neuron assemblies, that individual neurons do not possess". He metaphorically explains it thus "The brain and some of its sub-systems can mind i.e. be in mental states-but the mind cannot mind even its own business because it has no more an independent existence than does mass alongside bodies or history separately from people". This emergentist materialism he claims is the only one "that enjoys the support of all the life sciences, that does not promote a quixotic reductionism, and that defends neuroscience against obstruction by obsolete philosophers and ideologies."

This brings me to my teacher Dr Wilder Penfield, himself a pupil of Sherrington, a great neuroscientist and a thinker, who spent his life studying patients suffering from epilepsy, stimulating their brain with gentle electric current under local anaesthesia and most meticulously recording their responses, physical and psychic. Based on this unparallel experience, towards the end of his life he attempted to answer these very questions. He observed that "There is no area of gray matter, as far as my experience goes, in which local epileptic discharge brings to pass what could be called "mind-action". And "There is no place in the cerebral cortex where electrical stimulation will cause a patient to believe or to decide". He further elaborated it thus, "The record of consciousness can be set in motion, complicated though it is, by the electrode or by epileptic discharge. An illusion of interpretation can be produced in the same way. But none of the actions that we attribute to the mind has been initiated by electrode stimulation or epileptic discharge". "But what mind does is different. It cannot be accounted for by any neuronal mechanism that I can discover". "And yet the mind seems to act independently of the brain in the same sense that a programmer acts independently of his computer, however much he may depend upon the action of that computer for certain purpose". Not to be misinterpreted at another place he bluntly states, "But to expect the highest brain mechanism or any set of reflexes, however complicated, to carry out what mind does, and

thus perform all the functions of the mind is quite absurd". Thus convinced he enunciated, "For my own part, after years of striving to explain the mind on the basis of brain action alone, I have come to the conclusion that it is simpler (and far easier to be logical) if one adopts the hypothesis that our being does consist of two fundamental elements". And "The mind is aware of what is going on. The mind reasons and makes new decisions. It understands. It acts as though endowed with an energy of its own. It can make decisions and put them into effect by calling upon various brain mechanisms. It does this by activating neurone-mechanisms. This, it seems, could not be brought about by expenditure of energy". "The certainty, to my mind is this: When we come to understanding man, we will see that the nature of mind and the nature of mind's energy is simple and easily comprehensible" (Penfield 1975).

It may be pointed out that Sherrington already in 1953 had discounted the possibility of mind being some kind of energy. After discussing the prevailing beliefs he concluded, "Progress in knowledge specially natural Science, has only made more clear that the spatial concepts for reaching notion 'energy' is, as it stands, powerless to deal with or to describe mind."

George Wald (1979) considered consciousness and cosmology to be the most intractable problems of science and felt that "consciousness seems to me to be wholly impervious to science". Working all his life with biology of vision he wondered, as to "what it means to see". He predicted, ".....that it never will become possible to identify physically the presence or absence of consciousness, much less its contents". To him "consciousness is not part of universe of space and time, of observable and measurable quantities, that is amenable to scientific investigation". Nevertheless he argued that consciousness in not just an epiphenomenon, a concomitant of our neural activity that we project on to physical reality. On the contrary, "all that we know, including all our science, it is in our consciousness. It is part, not of superstructure, but the foundations."

Delbrück (1969), a theoretical physicist turned biologist, inevitably deliberated on the question of relationship of mind to matter. Tracing the evolution of the universe and emergence of life, and of mankind in the present form, he stated that the two ways in which all life forms display both unity and continuity are the material biochemical sense and the psychological sense i.e. ability of the organisms to perceive and react. In this respect he concluded that "the difference between the mental and the physical is not at all a radical one, but one merely of degrees. In his Nobel Address, he stated, "Thus even if we learn to speak about consciousness as an emergent property of the nerve nets, even if we learn to understand the processes that lead to abstraction, reasoning, and language, still any such development presupposes a notion of truth that is prior to all these efforts and that cannot be conceived as an emergent property of it, an emergent property of biological evolution". One is left wondering if he really believed that consciousness or mind is a property of all living organisms or only the human beings.

These sentiments seem to be echoed in the writings of Von Weizacker (1971) in his Identity Hypothesis, "Consciousness and matter are different aspects of the same reality". Likewise Wolfgang Pauli (1952) stated "It would be most satisfactory of all if physis and psyche (i.e. matter and mind) could be seen as complementary aspects of the same reality". This led Wald (1979) to state, "that one has no more basis for considering the existence of matter without its

complementary aspect of mind, than for asking that elementary particles not also be waves"

Schrödinger, drawing upon the concepts of Delbrück which paved the way for Watson & Crick to unravel the genetic code was struck by the fact that living matter while not eluding the "laws of physics" as established till then is likely to involve "other laws of physics hitherto unknown, which, however, once they have been revealed, will form part of the science of self or mind, as that of the gene. He quoted this as his only motive for writing his book, "What is Life? Mind and Matter. He felt that just as the mechanism of heredity is "closely related to, nay, founded on the very basis of quantum theory", the mind should find an explanation in the same. Posing a question to himself; How can the events in space-time which take place within the spatial boundary of a living organism can be accounted for by physics and chemistry? He was, however, undettered by the inability of existing physics and chemistry to account for such events, because he felt confident that future developments would prove it to be so.

He was conscious of the great dilemma that while our world picture is yielded exclusively from the sense organs as organs of the mind, so that every man's world picture is and always remains a construct of his mind, yet conscious mind itself "remains a stranger within that construct, it has no living space in it, you can spot it nowhere in space."

I cannot resist quoting a very thought provoking statement which undoubtedly is the key issue. Reflecting upon an every day experience of the bright, joyful eyes with which your child beams upon you when you bring him a new toy or the heart rending farewell to a dear-one which brings tears to your eyes, he wonders!, "Let us with all the knowledge we have about it, follow such a "tender look" inside the body. We do hit there on a supremely interesting bustle or, if you like, machinery. We find millions of cells of very specialized build in an arrangement that is unsurveyably intricate but quite obviously serves a very far reaching and highly consummate mutual communication and collaboration; a ceaseless hammering of regular electrochemical pulses which, however, change rapidly in their configuration, being conducted from nerve cell to nerve cell, tens of thousands of contacts being opened and blocked within every split second, chemical transformations being induced and may be other changes as yet undiscovered. All this we meet and, as the science of physiology advances, we may trust that we shall come to know more and more about it. But now let us assume that in a particular case you eventually observe several efferent bundles of pulsating currents, which issue from the brain and through long cellular protrusions (motor nerve fibres) are conducted to certain muscles of the arm, which as a consequence, tends a hesitating, trembling hand to you to bid you farewell-for a long heart-rending separation, at the sametime you may find some other pulsating bundles produce a certain glandular secretion so as to veil the poor sad eye with a cape of tears. But nowhere along this way from the eye through the central organ to the arm muscles and the tear glands-nowhere you may be sure, however far physiology advances, will you ever meet the personality, will you ever meet the dire pain, the bewildered worry within this soul, though their reality is to you so certain as though you suffered them yourself-as in actual fact you do."

In the end Schrödinger offers his personal, "necessarily subjective" view of the philosophical implications of his "purely scientific" presentation, which may be of some interest to my physicist colleagues. He proposes,

"According to the evidence put forward..... the space-time events in the body of a living being which correspond to the activity of its mind, to its self-conscious or anyother actions, are (considering also their complex structure and the accepted statistical explanation of physico-chemistry) if not strictly deterministic at any rate statistico-deterministic". For the physicists he emphasises that "in my opinion, and contrary to the opinion upheld in some quarters, quantum indeterminacy plays no biologically relevant role in them.....". Elaborating his hypothesis further, on the basis of two premises, (i) My body functions as a pure mechanism according to the Laws of Nature, and (ii) Yet I know, by incontroversial direct experience, that I am directing its motions, of which I foresee the effects.....; he concludes that, "I think, that I-I in the widest meaning of the word, that is to say, every conscious mind that has ever said or felt "I"- am the person, if any, who controls the "Motions of the atoms" according to the Laws of Nature.

Ultimately Schrödinger alligns himself with the mystic philosophers in the phrase; Deus Factus sum (I have become God). He tends to lean towards the concept that the whole world is a project of the one undivided cosmic consciousness and each of us is an integral part of it. This notwithstanding his initial contention that, it is practically indubitable fact of experience that the manifestation of a higher intellectual life is bound up with the functioning of a highly developed brain.

According to Fritjöf Capra (1975, 1983), mind and matter need no longer appear to belong to two separate categories, but can be seen to represent merely different aspects of the same phenomenon. "Mind is the dynamics of self-organisation, and the brain the biological structure through which this dynamics is carried out". He extends his hypothesis further to propose, "In the stratified order of nature, moreover, individual human minds are embedded in the larger minds of social and ecological systems, and these are integrated into the planetory mental systems-the mind of "Gaia", if you wish- which in turn, must participate in some mind of universal or cosmic mind" (once again we seem to be leaning towards Vedantic philosophy).

At this point I cannot help referring to Professor D S Kothari, one of our Past Presidents, a physicist and philosopher (thus providing a proof for the complimentarity principle in himself). While quoting a few of his statements on the subject, I will urge all interested to read his several papers in original. Talking of "Atom and Self", he enunciated that there are two worlds (not to be confused with the three worlds of Popper and Eccles): The External World and the Internal World. "Atom or brain belongs to the external, objective world of space-time and matter energy. Self or mind belongs to the internal subjective World. The subjective (mental) World is not describable in terms of space-time and matter energy concepts, self or mind therefore lies outside natural science". Discussing the relative heirarchy of the two he commented, "If we insist on holding one of the two, the external world (Matter) and internal world (Mind), as the only reality or one more fundamental of the two, two options are open to us. We may take matter above mind or mind above matter.....We may be inclined to believe that matter is primary and mind an appearance, an epiphenomenon of matter. It accords with the usual presentation of the theory (or rather the doctrine) of the Darwinian evolution. But then there is this difficulty. The belief itself that mind is an 'appearance' of matter belongs to the mind. This belief, therefore, can be no

more than an appearance. It loses its reliability, its reality". He goes on to suggest, "If then a choice has to be made at all, it seems preferable to take mind as the primary reality and matter as secondary" *"Chetan* as primary and *Jada* as secondary". This he found in keeping with teachings of the Upanishads, "Everything that exists is either *Chetan* or for the *Chetan* (mind)."

Concluding Remarks & Future Perspectives

From the foregoing presentation, which some might consider confusing rather than illuminating, few basic non-controversial facts seem to emerge. There is little doubt that the brain plays an important role, in maintenance and manifestation of consciousness, even if it may not be considered to be solely responsible for it. It is also obvious that consciousness could not be ascribed to be the function of any specific region of the brain, notwithstanding clinical or experimental data favouring one or the other site. No doubt certain regions of the brain or some specific neuronal circuits seem to be primarily involved in some specific elements of consciousness like sensory perception, information processing, memory, emotion etc. I, on my own part, would favour the concept that brain functions in a holistic manner and not in piecemeal. During the last couple of decades the reductionist approach to study brain, at molecular, cellular, or net work level, has undoubtedly provided wealth of information. Thus individual neurons, their organelles, their membranes and receptors, their massengers, start to get well understood. There is much better information regarding the neural net works, their development, variability and plasticity, even with respect to some of the mental functions. The electrochemical parameters involved in such functions start to be known. Nevertheless, the way different net works combine to form whole systems, even the relatively simple ones like those concerned with vision or hearing, leave aside emotions, moods or feelings, are still obscure. Julius Axelrod has poetically expressed this, "The brain's electrochemical language is as rich and subtle as that of Shakespeare. And we are just beginning to learn our ABCS" (Bylinsky 1990).

It is also obvious that there are various levels or states of consciousness, differently designated, the innate, the reflex, the subconscious, the crude or the full, not to mention the mystic or the absolute, which need to be accounted for, not individually in isolation, but as interacting, overlapping, integrated phenomenon woven into a holistic fabric responsible for the unitary experience we are all familiar with. We are certainly nowhere near this goal. All the information we have gathered and continue to gather frantically, though necessary and important for resolving this mystery, is not likely to do so in absence of a new intuition or insight.

There are optimists who claim that with the emergence of new techniques and technologies, "all aspects of mind, including its most puzzling attribute-consciousness or awareness-are likely to be explainable in more materialistic way as the behaviour of large sets of interacting neurones" (Crick & Koch 1992). This statement coming as it does from one who contributed so much to unravel the mystery of the gene may lead us to believe that the twentieth century will complete the hat trick of solving the mystery of the most crucial elements of the universe, first the atom, then the gene and now the mind. Yet, as mentioned above all the researches uptodate still ellude the most basic question in respect to the third. In the words of Crick himself, referring to visual awareness, "We believe that once we have mastered the secret of this simple form of awareness, we may be

close to understanding a central mystery of human life: how the physical events occurring in our brains while we think and act in the world relate to our subjective sensations-that is, how the brain relates to mind.

There are others who consider consciousness wholly impervious to science or beyond science (Wald 1983, Sperry 1952, Schrödinger 1967, Popper 1977, Elliott 1992), not explainable on the basis of currently known principles of physics (Penrose 1991, Wigner 1969), being an energy of a kind not yet described (Penfield 1975). Then there are people like Fischback (1992) who wondered, "Whether brain is complex enough to account for the mystery of human imagination, of memory and mood". Yet everyone in the end feels that there is enough justification to continue our search for the correct answer, now that new opportunities have become available for experimentation not only by the neuroscientists, but psychologists and philosophers as well. Drawing hope from the story of the atom and the gene, it is believed that "a principle as simple as the genetic code or the periodic table in chemistry may yet emerge for the brain" (Sejnowski 1991).

Based on the experience gained during three decades of professional work as a neurosurgeon, some scientific investigations, a bit of introspection and more recently an exploration of wisdom of intellectual gaints from diverse fields, I, on my own part, am convinced that the mystery of consciousness is inexorably linked to the mystery of the brain. This mystery is more likely to be resolved, if ever it does get resolved, by a holistic approach to study the brain as is becoming possible now through investigations on human beings, fully conscious and in possession of all their mental faculties. Studies involving those who have full awareness and ability to express it are more likely to provide the answers, than the currently favoured, the Cartesian-Newtonian reductionist approaches searching for the molecules, the channels, the receptors, or specific neuronal circuits of the aplysia or drosophilla or the rats and cats or even rhesus, which are not known to be endowed with consciousness, atleast in the sense discussed above. No doubt this quest is difficult but the path could be made easier and better illuminated if the neurobiologists take alongwith them the natural scientists, the psychologists and the philosophers on this journey. Having said so, I would hasten to add that our sages and seers from antiquity have warned us that there cannot be, and is not, a single path to the ultimate truth.

There are enough unexplained observations which need to be resolved before the answer to the eternal question, of brain-mind and consciousness can be found. We have observed stimulation of the various parts of the brain to produce, movement but never the coordinated activity resembling even a simple voluntary act leave aside the graceful movements of the master pianist's fingers. Stimulation of the sensory areas of the brain results in crude sensations-numbness or tingling, but not one of a gentle touch of a loved one, a sensation of flashes of light but rarely the vision of beauty; a sense of sound but not even formed word leave aside a message of hope. Stimulation or focal abnormalities in the brain are known to produce fear or anger but not joy, laughter but not happiness. Certainly one has never been told by any patient that any such stimulation, electrical, chemical or spontaneous as in epilepsy produced a sense of curiosity or adventure, pity or piety, an original thought or an intuition, a feeling of compassion, love or faith. And the other way round as yet there is not the faintest clue as to how the identical

sensory stimuli in terms of their physical characteristics as simple as light touch, one from the loved one and the other from a despised one are distinguished by the brain. Yes, these are very real as each one of us present here will testify. These no doubt are integral part of our consciousness, which gives meaning to our life and makes it worth living. To understand the mechanisms underlying these would be the most challenging task of science, lest it is stated that in the ultimate test science failed. May I conclude by saying that the greatest gift of God is not life but consciousness, in all its many splendored dimensions, with its ultimate goal to know one self and ones Creator. The mechanism responsible for it is the greatest mystery of all for future generations to explore.

In the end, I crave your indulgence for having taken the licence, emboldened by my present fortunate position, to stray beyond the area of my work-the clinical neuroscience-to some unchartered paths. This has necessitated recourse to extensive quotations from the works and thoughts of others to whom I owe a sense of gratitude.

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