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THE PRESENT STATUS OF NEUROSCIENCES IN THAILAND

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Introduction

Over ten years ago, the rapid advances in the understanding of the structure and function of the human brain, through the most complex application of the scientific methods and technology, have brought together disparate neural and behavioural sciences in a unified, yet multidisciplinary, field of neuroscience. Since then, neuroscience has remained as one of the most challenging and ever progressing fields of biosocial sciences. In science[1-3] as well as in public media[4-6], it has become increasingly clear that further progresses in neuroscience is not only beneficial for the alleviation of human suffering from mental illness but also because science, which brings about social and technological development, results from mental conscious experience and thought processes that are uniquely human. If the biophysico-chemical basis of brain function were better understood, new dimensions of mental capability and technology would also be available to solve the survival problems facing mankind and to explore unexpected opportunities of human accomplishment. Therefore, in commemoration of the 30th year of Science Society of Thailand, it seems appropriate to make an assessment of the present status of neurosciences in Thailand, and to survey trends of research activities and possibilities of interfacing both basic and applied researches in various areas of neurosciences to the problems facing the national development. This article is not intended to be a complete review of all the scientific research investigations done in this country; however, some prominent areas of contribution and deficiency will be pointed out.

Foundation of Neurosciences in Thailand

According to an authority[7], modern neurosciences began in Thailand half a century ago with the teaching of classical neuroanatomy, which describes the struc-

ture of the human brain and nervous system, in the Department of Anatomy of the Faculty of Medicine, Siriraj Hospital. Dr. Hutasankas (who later received the noble title of Khun Kaya Vibhak Bisal) received the Rockefeller Foundation scholarship to study neuroanatomy as well as embryology and physical anthropology at the University of Michigan in Ann Arbor in 1928, and returned to be the first teacher of neuroanatomy in Thailand between 1929-1931. Teaching and research activities have been further developed and expanded in this department by Professors Sud Sangvichien and Bhuket Vachananda[8,9] who also received training in neuroanatomy at the University of Michigan.

During and after the Second World War, clinical neurology and neurosurgery became firmly established by Professor Chitr Toochinda, who was trained in Jena under Professor Hans Berger the inventor of the electroencephalogram (EEG), and by Professor Udom Poshakrisna respectively. With their efforts, the first EEG machine for the recording of human brain waves was installed at Siriraj Hospital.

In 1947, the second medical school was established at the Chulalongkorn Hospital in Bangkok with addition of many new scientists and clinicians in various areas of neurological sciences. Outside the two medical schools, Siriraj and Chulalongkorn, the mental hospital at Pak Klong Sarn, Thonburi, at that time often referred to as "the Hospital for the Insane", was developed into a modern neuro-psychiatric center, presently known as the Somdej Chao Phraya Hospital. Many pioneers, who helped in the development of this hospital, are also the founders of modern psychology and psychiatry in Thailand. Stereotactic and cryogenic surgery of the deep brain structures for the treatment of certain psychoses was introduced to Thailand between 1958–1960. In 1957, with the great effort of Professor Prasop Ratanakorn, a new neurological hospital was founded in Bangkok. Five years later this new hospital was expanded and became the first neurological research institute in Thailand. Later in 1964, the Neurological Research Foundation under the Royal Patronage was established to promote further progress in scientific and medical researches in neurosciences.

As for professional society, the Neurological Association of Thailand was founded in 1959, with its memberships primarily from clinical neurologists and neurosurgeons. The association has contributed significantly to the postgraduate training course and for the periodic meetings and symposia. In 1975, the 4th Asian and Oceanean Congress of Neurology was held simultaneously with the 4th Asian and Australian Congress of Neurological Surgery in Bangkok. With many years of correspondence between local neuroscientists, UNESCO and the International Brain Research Organization (IBRO), Thailand received the honour to organize an International Workshop on Basic Neurosciences in Bangkok between February 12 and March 4 of 1978. Following this international exchanges, neuroscientists in Thailand have been elected to the membership in IBRO and other rapidly growing international societies for neurosciences.

At the present time (in 1978), neurosciences in Thailand are represented by both basic and clinical aspects of neuroanatomy, neurobiology, neurophysiology, neuropharmacology, neurochemistry, neuroendocrinology, neuropathology, neurology, neuroradiology, and closely related fields of behavioural biology, psychology and psychiatry.

Neuronatomy

There are many neuroanatomists and anatomists who are involved in teaching and research in various areas of neuroanatomy in all medical schools in Thailand. Most of these schools have a separate neuroanatomy course for medical and other health science students, while at the Faculty of Science of Mahidol University and at Chulalongkorn Medical School, it is integrated with other disciplines of neurological sciences.

Since the understanding of the organization of various neuronal pathways in the brain is a major prerequisite in the understanding of brain function and pathological manifestation in mental illness, the main interests of many Thai scientists in various schools have been the experimental study of neuronal organization and connections at various levels in the central nervous system[8,25]. Interestingly, a number of investigations spanning over 20 years have been concentrated on the study of nerve fiber connections to and from the cerebellum, which is known to be important in the control and coordination of body and eye movements. With the classical degeneration technique and silver impregnation methods, laminar patterns of fiber arrangement were described in the posterior columns of the spinal cord and their nuclei of the rhesus monkey[8]. In the same experimental materials, somatotopical patterns of the spinal afferent fibers which constitute the major spinocerebellar systems were studied in details from the level of the spinal cord to the brain stem, the inferior cerebellar peduncle and the projection areas in the cerebellum[9]. In the rhesus monkey[9] and in the opossum[11], the organization of the cerebellar corticonuclear projections and, in the latter species, the projection of the cerebellar cortical fibers to the vestibular complex were also studied. In collaboration with Norwegian neuroanatomists, the study of vestibular commissural connections[10] has contributed significantly to the understanding of neuronal mechanisms for the vestibular control of eye movements and body posture.

In another study[12] with the degeneration technique, the pattern of fiber projections in the visual system of the dog was investigated in detail. Since the classical degeneration technique has several limitations and often produced minor errors in the interpretation, the retrograde transport of tracer macromolecules e.g. horseradish peroxidase (HRP), a protein extracted from the root of horseradish, has been introduced in to the study of neuronal connections. With the collaboration of the Anatomical Institute, University of Oslo, a sensitive method[20] for the study of cerebellar afferent fiber systems[13-18, 23-25] by the retrograde transport of HRP has been developed in the Laboratory of Neurobiology and the Department of Anatomy of the Faculty of Science, Mahidol University. With this method, details of the new information on the localization of nerve cells of fiber origins, and organization of the projection area in various zones of the cerebellum have been made possible[13,18]. The demonstration of reciprocal connections between the cerebellum and the perihypoglossal nuclei[13,16,21], whose axons project to the motoneurons innervating extraocular muscles, have stimulated further interests in the neuronal mechanisms for the control of gaze by various brain stem neurons[13]. During the HRP study, it was accidentally found that nerve cells in many group of motor cranial nerve nuclei also project their axons

to the cerebellum[14]. Although the full functional significance of this finding is still under intensive study, it has already initiated a new concept in the neural control of movements. With the projection from these motoneuronal pools to the cerebellum, the central nervous system can monitor and precisely control the traffic of nerve impulses before sending them to certain groups of muscles. Such a control system has been speculated for sometime but there was no solid anatomical evidence until the HRP study. The sensitivity of the HRP method clearly promises to add new information sufficiently to revise many chapters of standard textbooks on classical neuroanatomy.

In a series of the HRP study in the cat, new details of information on the cerebellar afferent systems were obtained from studies of the primary vestibulocerebellar fibers[15], originated from axons of vestibular ganglionic neurons; the secondary vestibulocerebellar fibers[17] from neurons in the vestibular nuclear complex in the brain stem; from the inferior olive[18], the paramedian reticular nucleus[24], and the nucleus of tractus solitarius[25]. Research work in this aspect of modern experimental neuroanatomy is now expanded to other neural center in the brain[21,22].

The use of electron microscope for the study of synaptic degeneration was made in a study on the rubrospinal projection[19] in correlation with the study of neurons in the fiber terminal zone with the Golgi preparation.

Neurobiology

The boundaries of neurobiology greatly overlap with many old and new disciplines of neurosciences. In many instances, the term "neurobiology" is also used interchangeably with the term "neurosciences". However, it will be used in the present article just to include various studies of the biology of the nervous system in nonhuman experimental models, especially, in the lower vertebrates and invertebrates. The main objective of these studies is not to understand the functional details of how the human brain works, but rather to elucidate the general biological characteristics of the animal nervous systems, how they serve various behavioural purposes in different animals, and the evolutionary and ontogenic differences between different species of animals.

In a comparative study[26], the spinal shock, which is defined as the state of areflexia or hyporeflexia following the transection of the spinal cord, and the convulsion produced by an injection of strychnine were studied in many species of local amphibians and reptiles. Differences in the duration of the spinal shock time and the time of onset of strychnine convulsion were related to differences in the degree of encephalization, especially, in terms of relative amounts of supraspinal inhibition and facilitation among the species of animals.

Employing more sophisticated neuroanatomical and neurophysiological research techniques, the neuronal circuitry and the functional organization in the cerebellum of lower vertebrates have been studied for many years in the Laboratory of Neurobiology, Faculty of Science of Mahidol University[27-39]. With the ablation[30], electrical

stimulation[30] and local cooling[27] of the cerebellum in the goldfish. it was shown that, similar to higher vertebrates, the cerebellum of fish functions in the coordination of movements, and can be used as a simple experiment model for further investigations on its neuronal functions. Subsequent studies showed that the neuronal circuitry[31] and the functional characteristics of each neuronal component[28,29,36] were remarkably similar to those in the cerebellum of higher vertebrates. With the basic knowledge of the neuronal circuitry, it was also possible to investigate the mechanisms of neural information processing by the cerebellar neurons[37]. The interactions between the cerebellum and the visual system have now been investigated[35,39] in an attempt to understand the functional role and neuronal mechanisms for the control of eye movements by the cerebellum.

In the peripheral nervous system, the electrophysiological study[40] of the local species of frog revealed complex mechanisms for synaptic transmission between the preganglionic nerve fibers and the postganglionic sympathetic neurons. Applications of various pharmacological agents to the preparation made it possible to conclude that the release of acetylcholine from the presynaptic nerve terminal produced the activation of at least two distinctive cholinergic receptors on the postganglionic neurons[41]. One of these synaptic receptors is related to the mediation by cyclic nucleotide. The evidence indicates the possibility of an interneuronal system in the ganglia which releases the catecholamine in mediating the synaptic inhibition. These findings have made the sympathetic ganglia of local species of frog suitable for further study of complex problems on synaptic transmission. The preparation can also be useful for studying and testing other chemicals and drugs with potential actions on the cholinergic and catecholaminergic synaptic transmission.

Neurophysiology

Research contributions of Thai scientists in this field of neuroscience are mainly in the visual system[42,49-51], the central control of cardiovascular and respiratory movements[43,45], and the control of voluntary eye movements by the frontal cerebral eye field in the monkey[46-48]. In addition, neurophysiological research techniques have also been used in the study of neuronal mechanisms in the hypothalamus and other related brain structures implicated in the control of hormonal release by the pituitary[81-84,86-88]. This latter area will be described in subsequent section in relation to the research work on neuroendocrinology. In a series of study[42,49], average evoked responses were recorded from the superior colliculus of developing rabbits following a photic stimulation to investigate the postnatal development of the visual projection from the retina to the superior colliculus. Before the opening of the eyes, the latencies of the evoked responses were variable and not related to the positions of visual receptive field. After the eyes open, the responses with short latencies tend to be located close to the areas of the receptive field corresponding to the parts of retina in which the ganglionic cells are most densely packed. These ontogenetic changes were presumed to be due to mechanisms subserving sensory transduction and synaptic transmissions rather than variations in the conduction velocities of

axons of ganglionic cells which project to the superior colliculus. In another study in the cat[50], specific details on receptive fields of single neuronal units in the nucleus interlaminalis medialis of the lateral geniculate and the superior colliculus were investigated by microelectrode techniques. The work contributed some interesting information on the functional characteristics of these two areas of the brain which receive direct visual projections from the retina and are reciprocally connected to the visual cortex.

In lower vertebrates, the organization of the retina and the subcortical neuronal systems is more complex[51]. Neuronal circuitry in the optic tectum, pretectal area, and the thalamus of fish and frogs are known to serve specific aspects of the visual-orientation, visual search and prey-catching behaviours. Comparative neurophysiological studies in these experimental models may lead to the neural basis of some stereotyped visual oriented behaviours in the near further.

In the rabbit, electrical stimulation of the cerebellum in the cortex produced a decrease in the arterial blood pressure while the stimulation of the cerebellar nuclei, especially, the fastigial nucleus produced a marked increase in the arterial blood pressure[43]. These stimulations also produced certain alterations in the respiratory movements depending on the location of the electrodes in the cerebellum. Subsequent investigations showed that these cerebellar influences on cardiovascular and respiratory functions are possibly mediated by a pathway starting from axons of Purkinje cells in the cerebellar cortex of the vermis to the fastigial nucleus which relays these influences to cardiovascular and respiratory centers in the brainstem[44-45]. Present physiological evidence indicates that the cerebellum may play an important role in phasic control mechanisms for stabilization of the cardiovascular functions during movements, postural adjustment and, possibly, during certain stereotyped behaviours e.g. rage and defence reaction.

In higher vertebrates including man, the precision by which the animals can control their eye movements, and the feasibility to characterize and quantitate various patterns of eye movements have recently attracted many neurophysiologists working in the area of the central control of movement. At the Faculty of Science of Mahidol University, the functional role and neuronal mechanisms of the cerebral frontal eye field have been investigated for many years[46-48]. Electrical stimulation by chronically implanted microelectrodes in this area of the brain in the monkey produced a bilateral conjugated saccadic eye movements to certain point of visual fixation[47]. Experimental findings made from different regions in the frontal eye field suggest that the vectors for eye movements may be topographically represented in this areas similar to the representation of body movements on the primary motor cortex in the precentral area of the brain. Recording of neuronal unit activities[48] in the frontal eye field of the monkey provided further experimental evidence that this area of the brain may function as a trigger mechanisms for saccadic eye movement to occur at certain time sequence in series of complex coordinated behaviour rather than generating the patterns of the movement.

Neuropharmacology

The effect of L-dopa, an intermediate in the synthesis of dopamine which has been used in the treatment of Parkinson's disease and other movement disorders, has been studied on the electrical activities of the cerebral cortex and the caudate nucleus in the laboratory rat [52-53]. Basic research work along this line is necessary for understanding of the complex mechanisms of drug actions at various sites and synaptic transmitter systems in the brain in order to develop better concept for the therapeutic use of the drug. In another group of studies [54-56], the effects of morphine and other opiate antagonists were studied on the contraction of rat diaphragm [54], the action potential and antidromic activity in the rat phrenic nerve [55], on catalepsy, motor activity and electrical activity of the brain in rats [56]. Although these experiments may contribute some understanding on the nature of opiate actions at various sites and may serve as experimental models to study various opiate antagonists, they have not yet contributed much to understanding of more central issues in opiate neuro-and psychopharmacology, e.g. the mechanisms of analgesia, and the narcotic effects of these drugs.

One of the significant area in the research contribution of Thai scientists is, perhaps, the study of various drugs, and medicinal plants which may be potential antisnake venom drugs [57-64]. At Chiang Mai University, the effects of Wan Ngu (*Curcuma*, Sp., Zingiberaceae) [57-59], tetraethylammonium and 3-OH phenyl triethylammonium [64], neomycin and streptomycin [62-63], and Kloi (*Dioscorea*, Sp., Dioscoreaceae) have been studied on the neuromuscular transmission using the rat phrenic nerve-diapharagm muscle preparation. The therapeutic effectiveness of these drugs as antisnake venom in human still remains to be established.

In a series of studies [65] at the Faculty of Science of Mahidol University, the effects of various tetraalkylammonium ions in producing spontaneous and repetitive after-discharge activities were investigated on the rat sciatic nerve. Lowering the calcium concentration in the preparation depressed these spontaneous and evoked activities in the nerve [66]. These experimental findings support the well known hypothesis on the role of calcium in excitable membranes.

Very recently the microiontophoretic technique has been used [67-70] in the study of effects of the chemicals and drugs on nerve cells and synaptic transmission. Using multibarrel micropipett, the effects of acetylcholine, aminobutyric acid, dopamine, serotonin, bicuculline, DL-homocysteate, and tetanus toxin were studied on the spontaneous activities of neurons in the substantia nigra and their evoked synaptic responses to the stimulation of the caudate nucleus [67-69]. One of the interesting findings is that tetanus toxin can antagonize the effects of γ-aminobutyric acid, which mediates a synaptic inhibition on neurons of the substantia nigra without any discernable effect on the spontaneous activity.

In another iontophoretic study, histamine inhibits the activity of neurons in most parts of the vestibular complex and adjacent reticular formation in the brain stem of the cat [70]. Nerve cells which were excited by histamine were found mainly in the lateral vestibular nucleus. Metiamide, a specific H_2-receptor blocking agent,

was only effective in blocking the inhibitory effect of histamine and cimetidine, another receptor blocker, was ineffective in the experiment. It is clear that this preparation and metiamide can be very useful in studying and testing other potential histamine antagonists.

Neurochemistry

There is still a very limited amount of publications in this field of neurosciences by Thai scientists. In a study of the brain of Simese crocodile *(Crocodylus siamensis)*[71], the serotonin content and concentration of the whole and in various regions of the brain were studied by the spectrofluorometric assay technique. There appears to be some seasonal variations in the brain content of serotonin which show higher brain content in October than other months of the year, but exactly how serotonin is possibly involved in the animal periodic or annual changes of behavioural activities is not cler.

Since it is realized that both basic knowledge and research activities in modern neurochemistry are essential for solving many biological and clinical problems, e.g. neurochemical basis of learning and memory, transmitter neurochemistry, changes in brain chemistry in psychoses, etc., some efforts should be made by various institutions in Thailand to encourage potential young scientists to move in to this field of neurosciences.

Neuroendocrinology

Most studies in Thailand in this field are concentrated either on the neural controls of the release of hormone from the anterior pituitary in relation to ovulation[72-80], or the control of the release of oxytocin and vasopressin from the neurohypophysis[81-84, 89-91].

In a series of classical studies[72-73], the neural pathway which mediates the ovulatory surge of gonadotropin secretion was investigated by transections of the hypothalamus at different levels using the modified Halasz knife. The experimental evidence indicated that the pathway from the medial preoptic nucleus to the medial basal tuberal region, i.e. preoptico-tuberal pathway, which is concerned with the ovulatory surge mechanism for the release of LH·RF, exists as a diffuse neuronal system. However, bilateral transection at the level of suprachiasmatic nucleus extending 1.4 mm laterally in the rat brain blocked both spontaneous ovulation as well as ovulation in response to the stimulation of medial preoptic area. In another study[73], the effects of different lighting conditions and the "critical period" for the ovulatory mechanisms which can be blocked by an injection of general anesthetic, e.g. sodium pentobarbital, were investigated in two different strains of rat. It was shown that certain strains of rat may have a relatively long critical period beginning before 13.30 and lasting beyond 17.00 PM. At the Faculty of Science of Chulalongkorn University, many aspects of neuroendocrinology have been studied along with the reproductive

biology in the golden hamster[75-80], and in the monkey. The main part of the study concerns the possible role of various biogenic amines and hormones in the regulation of hypothalamic differentiation [79] and the control of adult gonadal function. Melatonin, a pineal hormone, was suggested to play a role in determining the onset of reproductive function. In another study [80], the role of biogenic amines in the regulation of the luteotrophic hormone secretion required for blastocyst implantation was investigated in the golden hamster. Apparently, the golden hamster is different from the rat in that the combination of prolactin and FSH is needed for the maintenance of pregnancy in hypophysectomized golden hamster, whereas in the rat prolactin may exert either luteotrophic or luteolytic effect depending on physiological condition of the corpus luteum. Daily injection of reserpine, which depletes various biogenic amines in the brain, suppressed endogenous release of FSH required for progesterone secretion and blastocyst implantation. Melatonin and monoamine oxidase inhibitor, e.g. Masilid and Marplan, were capable of reversing these effects of reserpine. The mechanisms by which these biogenic amines, which are putative neurotransmitters in various brain regions, participate in the control of hypothalamic hormones are not yet known.

For several years many scientists working in the Faculty of Science of Mahidol University have been interested in the paraventricular nucleus, which is known to contain neurons that produce oxytocin. Using electrophysiological techniques, the presence of recurrent collateral inhibition, through a Renshaw type interneurons, was demonstrated in the paraventricular nucleus by the electrical stimulation of their axons in the neurohypophysis [81]. These neurons could be excited as well as inhibited by electrical stimulation of either the septum or the central amygdala nucleus. In another study [82], responses of paraventricular neurons to vaginal distension and pinching of the foot were studied during various stages of the reproductive cycle and in ovariectomized rats either with or without oestrogen or progesterone pretreatment. Paraventricular neurons were found to be highly responsive to vaginal distension during prooestrus, oestrus, at full term and immediately after parturition and during lactation, but were less responsive during metoestrus and in mid-pregnancy (day 12). Pinching of the foot also excited the paraventricular neurons, but they do not exhibit the same patterns of variation during the reproductive cycle. The experiments indicate that the hormonal levels during various periods in the reproductive cycle can influence the responsiveness of the paraventricular neurons to certain somatic afferent input. Detailed electrophysiological study of the paraventricular nucleus [83,84] indicated that their neurons may be heterogenous in their spontaneous activities and patterns of response to various afferent inputs.

The investigation in this laboratory also extended into the nucleus accumbens which is a medial forebrain structure usually considered as part of the emotional or the limbic system [85,86]. Electrical stimulation of this nucleus [86] could activate or inhibit activities of neurosecretory cells in the paraventricular nucleus, and the stimulation of the neurohypophysis, the paraventricular nucleus or the olfactory tubercle could also excite neurons in the nucleus accumbens. Therefore, it was suggested that the nucleus accumbens may play a role in neuroendocrine regulation. The suggestion was further supported when it was found that lesions of the nucleus accumbens

impaired lactational performance and maternal behaviour which could be attributed to deficiency of oxytocin and also possibly some insufficiency of prolactin. Recently, the research interests have been focused on the arcuate neurons of the hypothalamus, whose axons project to the median eminence and serve as the final common path for the regulation of the release of gonadotrophic hormones[88-89]. The electrophysiological study[87] revealed that the septum, the medial preoptic and the arcuate nuclei are interconnected by reverberating circuits. In addition, the arcuate neurons which project to the median eminence could be activated by the electrical stimulation of the basolateral amygdala nucleus indicating the possibility of extrahypothalamic influence which is involved in the regulation of gonadotrophin secretion. What remains to be investigated now is the functional roles of all these interconnections to the hypothalamic regulatory areas in various phases of neuroendocrine controls during the reproductive cycle.

In a series of collaborations with a group of American scientists[89-91], the neural mechanisms which trigger the release of vasopressin were investigated in the monkey. Nicotine infusion[89] and electrical stimulation of the neuroendocrine pathway[90] including the amygdala, the hypothalamus were found to produce an increase in the blood level of arginine vasopressin as detected by the radioimmunoassay technique. More interestingly, the behavioural state of animal seemed to be a major determinant for the release of vasopressin from the neurohypophysis. In addition, there is a circadian variation of the blood level of vasopressin with peaks at midnight during sleep and decrease to the low levels at noon during waking. It is now evident that chronically implanted conscious animal preparation may provide further opportuntiy for neuroendocrinologists to simultaneously study the functional roles as well as the neuronal mechanisms for the control of hormonal release and circulating blood levels in relation to various behavioural states in the animal.

Neuropathology

Although neuropathology in Thailand exists as a division of the general and clinical pathology, it is, perhaps, one of the strongest and well established areas of neurosciences in Thailand, as evidenced from various publications[92-105], Various forms of tumor of the nervous systems have been studied in details[102-104]. In addition, the accessibility of specimens from many medical schools, especially, from Siriraj and Chulalongkorn Hospitals, have made it possible to investigate 2,897 cases of tumors of the nervous system in Thailand[104], which is perhaps one of world largest series as far as the number of the cases collected for the report.

In collaboration with the University of Virginia, the Department of Pathology of Chulalongkorn Hospital has produced excellent works on the paraphysis and the choroid plexus both in lower vertebrates and in the human[93-101]. Comparative studies in many species of vertebrates[96] and in human embryos[93,97,98] indicate that the paraphysis, the structure originated from the rostral end of the roof of the diencephalon, and the choroid plexus are derived from the same neuroepithelium lining of the neural tube. Both structures are consisted of epithelial cilia and tubules, and

contain mucin and mucopolysaccharides within the epithelial cytoplasm[98]. It was suggested that the paraphysis should also be appropriately called the "extraventricular choroid plexus". These basic neuropathological studies have made it possible to understand the tissue origin of the colloidal cysts[95,99-101] which were found in various regions of the brain, where the neuroepithelium is present, in several pateints.

In Thailand as well as in other tropical developing countries, infection of the nervous system, especially, the central nervous system, is still one of the major medical problems[92,105]. Tetanus continues to be one of the leading causes of death, particularly in newborns and infants in Thailand. However, the pathophysiological mechanisms by which tetanus toxin could affect the nervous system have not yet been fully investigated and should be encouraged in the near future. Certain parasitic infestations of the brain, e.g. cysticercosis, and larva migration of *Angiostrongylus cantonensis*, and *Gnathostoma spinigerum* in the neural axis are frequently reported[92]. It was believed that the eosinophilic meningitis, a common malady, was a consequence of the migration of these parasitic larva in the nervous tissue. Recently, various forms of cerebral malaria have reappeared and, in many cases, they appeared to be chloroquine resistant. It is surprising that, inspite of being an ancient malady, there is very little knowledge of the pathophyisological mechanisms of cerebral malaria. It is still not certain whether the malarial parasite itself, or their toxin, or the break down of the body cells and tissues or, possibly, the autoimmune mechanisms is the causative agent of all symptoms in cerebral malaria. In some of these areas, basic neuropathological studies by Thai scientists may have many potential benefits for solving current medical problems of the world.

Clinical Neurosciences

Clinical neurosciences in Thailand are well established in all medical schools and many large servicing hospitals. However, there are still very few basic clinical researches in these fields of neurosciences beyond case reports and investigation of the prevalence of various diseases on the nervous system in Thailand[105]. In Bangkok, cerebrovascular accident, infection of nervous system and epilepsy are the most frequent neurological disorders observed by general practicing neurologists while diseases of the spinal cord, tumor of the nervous system, demyelinating disease, peripheral neuropathies, neuromuscular disorders, and various degenerative diseases are occasionally found among local patients[105]. In clinical neurosurgery, injuries of the nervous system, especially those resulted from head injuries by auto or industrial accidents, constitute the largest group of patients. Frontoethmoidal meningoencephaloceles are more common in Thailand and other Southeast Asian countries than in other regions of the world[92,105]. Recently, metabolic and toxic disorders which affect the nervous system became frequently reported[92]. Some of these maladies can be traced to environmental toxicity such as lead, manganese and methylmercury poisonings. Reye's syndrome, or the encephalopathy and fatty degeneration of the visceral organs, is common in the Northeastern past of Thailand. The cause of this malady is unknown but the most probable one is the toxicity of alflatoxin produced

by some strains of fungus, *Aspergillus flavus*. It would be extremely profitable to study the effect of the toxin on some experimental model to obtain further understanding of its mode and mechanisms of action. Such a study would reveal tactical approach to prevent and cure this fatal disease.

In clinical neurology, electrophysiological techniques have been used to study and follow up the clinical progress of patients in Bell's Palsy[106], cubital tunnel syndrome[107], and posterior interosseus nerve paralysis[108].

In an experimental neurosurgical study[109], the effects of bilateral section of the cerebral peduncles were studied in the rhesus monkey. The experiment showed that degeneration of the pyramidal tract in primates does not result in the well-known "pyramidal syndrome" of paralysis, spasticity, and increased tendon reflexes. Both monkey and man are capable of useful movement after destruction of the pyramidal tract in the cerebral peduncle. The finding is contradictory to the concept held in many classical textbooks but is in good agreement with the present hypothesis derived from modern neurophysiological studies that the pyramidal tract neurons regulate mainly the force of the movement[3]. In another series of neurosurgical study, new methods were developed for the relief and treatment of syringomyelia[110] and hemifacial spasm[111]. Clinical observation and experimental study with a peripheral nerve model indicated that the spasm of the facial muscles in the patients may be produced by mechanical stimulation of the peripheral part of the facial nerve during its course in the internal auditory canal by an arterial loop[111].

In neuroradiology, both angiography[112,113] and radioactive brain scanner have been widely used for diagnostic purposes. Recently, X-ray computerized tomography has also been introduced into Thailand. However, there has not been significant contribution in this field of neuroscience by local scientists and doctors.

Other Related Fields of Behavioural Biology, Psychology, and Psychiatry

Study of the mind and behaviour as a unified science of behavioural biology is rather new to Thailand. In the Department of Biology of Mahidol and Chulalongkorn Universities, however, some basic studies in the field of behavioural biology have been developed[114-117]. Several attempts have been made to study both social and individual behaviour of the gibbon, one of the endangered species in Thailand[114-115]. These studies should be more encouraged and supported since they are essential to the problem of wildlife conservation and to repopulated this endangered species before its extinction from Thailand.

The behavioural responses of cuttlefish to different intensity of light[116] and the behaviour of living caecilians in captivity[117] have also been reported. It is hoped that there will be more encouragements for these studies of animal behaviours for the basic knowledge of our nature as well as its application to ecological conservation.

Interfacing Neuroscience Researches to Solve Current Problems

It has recently become clear that early malnourishment[118], lack of proper environmental stimulation, and, more severaly, parental deprivation[119] during the critical period of child development can adversely affect the developing brain and produce persistent deficiencies of mental and behavioural development. Therefore, early malnourished and lack of environmental stimulation in Thai children have resulted in population with lower mental capabilities and various forms of mental health problems[119]. It has been estimated that between 5-6 million children under 6 years of age are suffering from varying degrees of malnutrition and, not surprisingly, most of these children have also been neglected and reared in poor developmental environments. The prevention of these problems involves complex socio-economic, cultural, and human factors. While basic researches have shown that early malnutrition in experimental animal, especially, with protein deficiency, could decrease the brain cell number, impair the development of dendritic processes and synaptic connections in relation to the reduced ability to perform in conditioned or learning tasks[119], very little is known of the real situation in the brain of malnourished Thai children. Attempts to rehabilitate these children with high protein supplementary diet have met several difficulties. It appears that food supplementation alone is not very effective in improving brain and mental function in these children although other body parameters can be easily improved by giving better diet. Experimental study in a group of children at the Ramathibodi Hospital[119] indicates that an increase in the environmental stimuli may strongly facilitate the improvement of both body and mental development. In some countries, e.g. the United States, and the Philippines, a "mental feeding" program have been launched to combat these problems in children and to improve their mental development. It is hoped that a combined effort from many scientific disciplines will be encouraged in this country to help solving this very important problem.

With increasing social pressures, it is not surprising to observe a rapidly increasing trend in the use of various narcotics and other drugs as a means to escape from reality. While several programs have been established to make a survey[120] and to study the possibility of setting up better rehabilitation programs, very little progress has been made in scientific researches on this problem in Thailand. At Chulalongkorn University, an effort have been made to establish experimental models in the laboratory utilizing a system for self-administering of drug to test the effectiveness of various opiates and narcotic antagonists, and the motivational aspects for the use of drug[121]. Lesions of certain brain locations have been shown to either increase or suppress the drug self-administered behaviour. Some studies have also been made on the distribution and localization of opiate receptors in various parts of the brain. Studies along this line will undoubtedly lead to better understanding of the neural mechanisms of narcosis, drug dependence, withdrawal symptoms, possibility of developing better antagonists or vaccine and, perhaps, also the understanding of important neural mechanisms for pain sensation[6] and rational development of new analgesic drugs.

General Comment

It is evident from the present survey that various areas of neurosciences have been established in Thailand. Some areas have been more fortunated and received larger proportion of interests while others only have just begun to develop. In one way or another, the areas, which have been well developed and are presently contributing to the progress, have received either some forms of international support or collaboration. It is hoped that deficiencies in other areas can be corrected by encouraging and motivating younger scientists to become interested in them. Collaborations and exchanges with international authorities may be very helpful both in laying down the foundation as well as promoting further progress. At the same time, further increases in local supports through both governmental and private channels can be very helpful. To gain these local supports, it will be necessary for local scientific researchers to move closer or toward current problems of the country or the community. However, provision must be made to support some scientists working purely in the area of basic researches. Without the basic knowledge, the ineffectual import of skill and technology will continue. Some areas in which basic researches may be directly beneficial to local problems have been pointed out. Finally, it is well recognized that many human and administrative factors still prevent collaboration among local scientists, the utilization of research facilities, and the exploration of our full potentiality. These problems do not only prevent further progress but also delay the application of basic researches for human welfare. The problems are not unique to neurosciences, and all disciplines of science in Thailand will progress far better without them.

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References

1. Quarton, G., Melnechuk, T. and Schmitt, F.O. (1967). *The Neurosciences: A Study Program.* Rockefeller University Press, New York.
2. Schmitt, F.O. (1970). *The Neurosciences: Second Study Program,* Rockefeller University Press, New York.
3. Schmitt, F.O., and Worden, F.G. (1974). *The Neurosciences: Third Study Program,* MIT Press, Cambridge, Massachusetts.
4. Newsweek magazine, June 21, 1971, pp. 60-68, Newsweek, Inc., New York.
5. Newsweek magazine, January 14, 1974, pp. 50-59, Newsweek, Inc., New York.
6. Newsweek magazine, April 25, 1977, pp. 42-47, Newsweek, Inc., New York.
7. Poshakrisna, U. (1978) *Proceedings of the International Workshop on Basic Neurosciences,* Bangkok, Thailand (in press).
8. Vachananda, B. (1959) *Anat. Rec.* **133,** 345.
9. Vachananda, B. (1959) *J. Comp. Neurol.* **112,** 303-351.
10. Ladpli, R. and Brodal, A. (1968) *Brain Res.* **8,** 65-96.
11. Sreesri, M. (1974) *J. Hirnforsch.* **15,** 529-544.

12. Sithi-amorn, C., Vongdokmai, R., Bardhanabaedya, S. (1975) *Abstracts of the Bangkok Science Symposium*, Bangkok, p. 27.
13. Kotchabhakdi, N. (1977) *Dev. Neurosci.* **1**, 119-130.
14. Kotchabhakdi, N. and Walberg, F. (1977) *Brain Res.* **137**, 158-163.
15. Kotchabhakdi, N. and Walberg, F. (1977) *Brain Res.* **142**, 142-146.
16. Kotchabhakdi, N., Hoddevik, G.H. and Walberg, F. (1978) *Exp. Brain Res.* **31**, 13-29.
17. Kotchabhakdi, N. and Walberg, F. (1978) *Exp. Brain Res.* **31**, 591-604.
18. Kotchabhakdi, N., Walberg, F. and Brodal, A. (1978) *J. Comp. Neurol.* **182**, 293-313.
19. Goode, G.E. and Sreesai, M. (1978) *Brain Res.* **143**, 61-70.
20. Siddhichai, A., Chindadoungratn, W. and Kotchabhakdi, N. (1977) *Abstracts of the Bangkok Science Symposium*, Bangkok, p. 166.
21. Yingchareon, K., Singhaniyom, W. and Kotchabhakdi, N. (1977) *Abstracts of the Bangkok Science Symposium*, Bangkok, p. 159.
22. Singhaniyom, W., Kotchabhakdi, N. and Somana, R. (1977) *Abstracts of the Bangkok Science Symposium*, Bangkok. p. 161.
23. Somana, R. and Walberg, F. (1978a) *Anat. Embryol.* **154**, 353-368.
24. Somana, R. and Walberg, F. (1978b) *Anat. Embryol.* **155**, 87-94.
25. Somana, R. and Walberg, F. (1979) *Neurosci. Lett.* **11**, 41-47.
26. Chairach, P. and Leitch, G.J. (1971) *Comp. Biochem. Physiol.* **38A**, 175-181.
27. Kotchabhakdi, N. and Prosser, C.L. (1972) *Proc. Soc. Neurosci.* **2**, 262.
28. Kotchabhakdi, N. (1975) *Abstracts of the Bangkok Science Symposium*, Bangkok, p. 161.
29. Kotchabhakdi, N. (1975) *Abstracts of the Bangkok Scicnce Symposium*, Bangkok, p. 162.
30. Kotchabhakdi, N. (1975) *Abstracts of the Bangkok Science Symposium*, Bangkok, p. 163.
31. Kotchabhakdi, N. (1975) *Abstracts of the Bangkok Science Symposium*, Bangkok. p. 183.
32. Kotchabhakdi, N. (1975) *Abstracts of the Bangkok Science Symposium*, Bangkok, p. 184.
33. Kotchabhakdi, N. (1975) *Abstracts of the Bangkok Science Symposium*, Bangkok, p. 185.
34. Kotchabhakdi, N. (1975) *Abstracts of the Bangkok Science Symposium*, Bangkok, p. 169.
35. Kotchabhakdi, N. (1975) *Abstracts of the Bangkok Science Symposium*, Bangkok, p. 170.
36. Kotchabhakdi, N. (1976) *J. Comp. Physiol.* **112**, 47-73.
37. Kotchabhakdi, N. (1976) *J. Comp. Physiol.* **112**, 73-93.
38. Friedlander, M.J., Kotchabhakdi, N. and Prosser, C.L. (1976) *J. Comp. Physiol.* **112**, 19-45.
39. Chindadoungratn, C. and Kotchabhakdi, N. (1977) *Abstracts of the Bangkok Science Symposium*, Bangkok, p. 165.
40. Tiloksakulchai, K. and Kotchabhakdi, N. (1975) *Abstracts of the Bangkok Science Symposium*, Bangkok, p. 173.
41. Tiloksakulchai, K. and Kotchabhakdi, N. (1975) *Abstracts of the Banghok Science Symposium*, Bangkok, p. 174.
42. Sitthi-amorn, C. (1974) *Proceedings of the International Union of Physiological Science*, New Delhi **XI**, p. 219.
43. Abdul Choliq Chuseri and Kotchabhakdi, N. (1975) *Proceedings of the 4th Asean and Ocean Congress of Neurology*, Bangkok, p. 14
44. Abdul Choliq Chuseri and Kotchabhakdi, N. (1975) *Abstracts of the Bangkok Science Symposium, Bangkok*, p. 178.
45. Abdul Choliq Chuseri and Kotchabhakdi, N. (1977) *Abstracts of the Bangkok Science Symposium*, Bangkok, p. 160.
46. Boonsinsukh, P. and Kotchabhakdi, N. (1975) *Abstracts of the Bangkok Science Symposium*, Bangkok, p. 106.
47. Boonsinsukh, P., Chindadoungratn, C. and Kotchabhakdi, N. (1977) *Abstracts of the Bangkok Science Symposium*, Bangkok. p. 163.
48. Boonsinsukh, P., Chindadoungratn, C. and Kotchabhakdi, N. (1977) *Abstracts of the Bangkok Science Symposium*. Bangkok, p 164.
49. Sitthi-amorn, C. (1978) *Proceedings of the International Workshop on Basic Neurosciences*, Bangkok, Thailand (in press).
50. Vejbaesya, C. (1978) *Proceedings of the International Workshop on Basic Nenrosciences* Bangkok, Thailand (in press).

51. Kotchabhakdi, N. (1978) *Proceedings of the International Workshop on Basic Neurosciences*, Bangkok, Thailand (in press).
52. Tannukich, Y. and Kuperman, A.S. (1975) *Asbstracts of the Bangkok Science Symposium*, Bangkok, p. 152.
53. Tannukich, Y. and Kotchabhakdi, N. (1975) *Abstracts of the Bangkok Science Symposium*, Bangkok, p. 153.
54. Setiawat, A. and Kuperman, A.S. (1975) *Abstracts of the Bangkok Science Symposium* Bangkok, p. 154.
55. Setiawati, A., Kuperman, A.S. and Kotchabhakdi, N. (1975) *Abstracts of the Bangkok Science Symposium* Bangkok, p. 155.
56. Laddawan, K. (1974) *Mahidol Univ. Annual Res. Abstracts*, p. 133.
57. Tejasen, P., Chantaratham, A and Kanjanapothi, D. (1969) *Chaing Mai Med. Bull.* **8**, 165-178.
58. Tejasen, P., Chantaratham, A. and Kanjanapothi, D. (1969) *Chiang Mai Med. Bull.* **8**, 229-236.
59. Chantaratham, A. and Tejasen, P. (1970) *Chiang Mai Med. Bull.* **9**, 73-87.
60. Chantaratham, A. and Tejasen, P. (1972) *Chiang Mai Med. Bull.* **11**, 103-109.
61. Apisariyakul, A. (1975) *Chiang Mai Med. Bull.* **14**, 209-219.
62. Nasode, B. and Apisariyakul, A. (1975) *Abstracts of the Bangkok Science Sgmposium*, Bangkok, p. 239.
63. Nasode, B. and Apisariyakul, A. (1977) *Chiang Mai Med. Bull.* **16**, 113.
64. Apisariyakul, A. (1977) *Abstracts of the Bangkok Science Symposium*, Bangkok, p. 155.
65. Wongwitdecha, N. and Kuperman, A.S. (1977) *Abstracts of the Bangkok Science Symposium*, Bangkok, p. 156.
66. Wongwitdecha, N. (1977) *Abstracts of the Bangkok Science Symposium*, Bangkok p. 157.
67. Davies, J. and Tongroach, P. (1977) *Br. J. Pharmacol.* **59**, 489.
68. Stranghan, D.W., Davies, J. and Tongroach, P. (1978) *Proceedings of the XXVII International Congress af Physiological Science*, (in press).
69. Tongroach, P. (1978) *Proceedings of the International Workshop on Basic Neuroscience*, Bangkok, (in press).
70. Satayavivad, J. and Kirsten, E.B. (1977) *Eur. J. Pharmacol.* **41**, 17-26.
71. Rujirekagulwat, T. and Huggins, S.E. (1975) *Gen. Pharmacol.* **6**, 133-140.
72. Tejasen, T. and Everett, J.W. (1966) *Anat. Rec.* **154**, 431-432.
73. Everett, J.W. and Tejasen, T. (1967) *Endocrinology* **80**, 790-792.
74. Tejasen, T. and Everett, J.W. (1967) *Endocrinology* **81**, 1387-1396.
75. Varavudi, P. (1969) *J. Endocrinol.* **43**, 237-245.
76. Varavudhi, P. and Pinyawat, V. (1971) *Abstracts of Fourth Asian and Ocean Congress of Endocrinology*, Auckland, New Zealand, p. 125.
77. Varavudhi. P. and Chobsieng, P. (1973) *Proceedings of IX Acta Endocrinological Congress*, Oslo, Norway. Suppl. **177**, 78.
78. Varavudhi, P. and Vachirodom, P. (1973) *Acta Endocrinol. (Copenhagen)* Suppl. **177**, 15.
79. Varavudhi, P. and Chulakasem, W, (1974) *Abstracts of the Symposium Southeast Asia Addresses Its Health Problems*, Mahidol Univ. Bangkok, p. 120.
80. Varavudhi, P. (1975) *J. Sci. Soc. Thailand.* **1**, 120-129.
81. Negoro, H., Visessuwan, S. and Holland, R.C. (1973a) *Brain Res.* **57**, 479-483.
82. Negoro, H., Visessuwan, S. and Holland, R.C. (1973b) *J. Endocrinol.* **59**, 112-122.
83. Holland, R.C., Pavasutipaisit, K. and Trivitayarat, C. (1973) *Mahidol University Annual Research Abstracts* p. 76.
84. Holland, R.C. and Pavasutipaisit, K. (1974) *Anat. Rec.* **178**, 377.
85. Smith, M.O. and Holland, R.C. (1975) *Physiol. Psycho.* **3**, 331-336.
86. Aswin, S., Pavasuthipaisit, K. and Holland R.C. (1974) *Abstracts of the Symposium, Southeast Asia Addresses It Health Problems*, Bangkok p. 122.
87. Foongdej, S., Trivitayaratn, C., Holland, R.C. and Pavasuthipaisit, K. (1975) *Abstracts of the Bangkok Science Symposium*, Bangkok, p. 158-159.
88. Foongdej, S., Pavasuthipaisit, K. and Trivitaynratn (1978) *Mahidol University Annual Research Abstracts*, Bangkok, p. 157.
89. Hayward. J.N. and Pavasuthipaisit, K. (1976) *Neuroendocrinology* **21**, 120-129.

90. Hayward, J.N., Murgas, K. Pavasuthipaisit, K., Perez-Loapez, F.R. and Sofroniew, M.V. (1977) *Neuroendocrinology* **23**, 61-75.
91. Hayward, J.N. and Pavasuthipaisit, K. (1977) *Proc. Soc. Neurosci.* **3**, 345.
92. Shuangshoti, S. (1978) *Proceedings of the International Workshop on Basic Neurosciences*, Bangkok, Thailand, (in press).
93. Shuangshoti, S. and Netsky, M.G. (1966a) *Am. J. Anat.* **118**, 283-316.
94. Shuangshoti, S. and Netsky, M.G. (1966b) *Am. J. Pathol.* **48**, 503-533.
95. Shuangshoti, S. and Netsky, M.G. (1966c) *Neurology.* **16**, 887-903.
96. Shuangshoti, S. and Netsky, M.G. (1966d) *J. Morphol.* **120**, 157-188.
97. Shuangshoti, S. and Netsky, M.G. (1970) *Am. J. Anat.* **128**, 73-96.
98. Netsky, M.G. and Shuangshoti, S. (1970) *Neurosci. Res.* **3**, 131-173.
99. Shuangshoti, S. (1975) *J. Med. Assoc. Thailand* **58**, 413-436.
100. Shuangshoti, S., Paisuntornsook, P. and Netsky, M.G. (1976) *Neurology* **26**, 656-658.
101. Shuangshoti, S., Netsky, M.G. and Switter, D.J. (1978) *Neurology* **28**, 552-555.
102. Shuangshoti, S. (1967) *J. Med. Assoc. Thailand* **50**, 721-736.
103. Shuangshoti, S. (1969) *J. Med. Assoc.* Thailand **52**, 217-226.
104. Shuangshoti, S. and Panyathanya, R. (1974) *Neurology.* **24**, 1127-1134.
105. Vejjajiva, A. (1973) *in Tropical Neurology* (Spillane, J.D., ed.) Oxford Univerity press, New York, pp. 335-352.
106. Boongrid, P. and Vejjajiva, A. (1973) *Mahidol University Annual Research Abstracts*, Bangkok, p. 262.
107. Boongird, P. and Bunyaratavej, S. (1973) *Mahidol University Annual Research Abstracts*, Bangkok, p 263.
108. Boongrid, P., Bunyaratavej, S. and Vejjajiva, A. (1973) *Mahidol University Annual Research Abstracts*, Bangkok, p. 265,
109. Bucy, P.C., Ladpli, R. and Ehrlich, A. (1966) *J. Neurosurg.* **25**, 1-20.
110. Bunyaratavej, S., Makarabhiromya, B., Dheandhanoo, D., and Vimolchalao, M. (1977) *J. Med. Assoc. Thailand* **60**, 149-157.
111. Bunyaratavej, S. (1978) *Proceedings of the International Workshop on Basic Neurosciences*, Bangkok, Thailand (in press).
112. Suwanwela, N. and Suwanwela, C. (1975) *Proceeding of the 4th Asian and Oceanian Congress of Neurology*, Bangkok, p. 128.
113. Suwanwela, N. and Suwanwela, C. (1975) in *Recent Advances in Diagnostic Neuroradiology*, (Kitamary, K. and Newton, T.H. eds.) Igaku Shoin, Tokyo pp. 150-155.
114. Brockelman, W.Y., Ross, B.A. and Pantuwatana, S. (1973) *Amer. J. Phys. Anthropol.* **38**, 637-640.
115. Srikosamatara, S. (1978) *Abstracts of the Seminar on Primate Research in Thailand*, Bangkok, Mahidol University.
116. Yodyingyuad, U. Sithigorngul, P. Satayalai, O., Siripoon, P. and Boonprakob, P. (1977) *Abstracts of the Bangkok Science Symposium*, Bangkok, p. 183.
117. Israngkura, K. (1977) *Abstracts of the Bangkok Science Symposium*, Bangkok, p. 198.
118. Valyasevi, A. (1978) *Proceedings of the International Workshop on Basic Neuroscience*, Bangkok (in press).
119. Kotchabhakdi, N., Kajanathiti, P., Tantiserene, K. (1978) *Proceedings of the International Workshop on Basic Neuroscience*, Bangkok (in press).
120. *Semiannual Report on Drug Dependence Research Program*, Institute of Health Research, Chulalongkorn University, Bangkok, January-June, 1977.
121. Sitthi-amorn, C. (1978) *Proceedings of the International Workshop on Basic Neuroscience*, Bangkok (in press).