CHAPTER 6

MEDICAL NEUROSCIENCE AS AN INSTRUMENT OF HERMENEUTICS TO STUDY PATANJALI YOGA SUTRAS

Medical neuroscience is used in this study as the main instrument for the hermeneutic interpretation of the Patanjali Yoga Sutras. This section reviews the relevant aspects of medical neuroscience to justify its use as a valid and reliable instrument for hermeneutic analysis and interpretation of the Yoga Sutras.

6.1 Overview of Recent Advances in Medical Neuroscience
(Neuroscience 2012, Purves et al 2011)

The brain and the nervous system is the most complex living system in the universe. The extent of the capabilities of the brain is not known. The brain coordinates and influences every aspect of the body and functions. Every other system of the body is regulated by the brain and nervous system. Brain also influences human behaviours - actions, emotions and thoughts.

The nervous system is composed of nerve cells which are over a trillion and dynamically organize themselves into multiple functional networks that remain functional throughout the lifetime. The two main reasons for human medical neuroscience research is to learn and find cures for or prevent disorders affecting the brain and nervous system, and to better understand human behaviours.

Over the last two decades several significant advances have happened in medical neuroscience. There have been advances in genetics with identification of key genes in the pathology of brain disorders including Alzheimer’s disease, Huntington’s disease, Parkinson’s disease and Amyotrophic Lateral Sclerosis. The mapping of the human genome has now made possible further research into identifying disease causing genes and finding new and novel treatments and preventive strategies.
Gene-Environment interaction is another major area of study also relevant in mechanisms of yoga practice. It is the study of how environment affects gene expression including effects of toxic substances, diet, stressors and lifestyle including physical activity and mental states.

One significant development in recent times is the progress in neuroplasticity. Neuroplasticity in the ability of the brain to change adaptably to new circumstances either from inputs from the outside environment or internal mental phenomenon as in psychotherapy and meditation. The uncovering of the molecular basis of neural plasticity is providing new insights into brain and nervous system functions, learning and memory functions, pain and chronic pain mechanisms and aspects of disease modifications and novel treatments for neuropsychological disorders. Brain cells can not only modify their structure and circuitry but also can be generated in the adult brain called neurogenesis further contributing to neuroplasticity.

Advances in molecular neuropharmacology has led to better understanding of molecular mechanisms in disorders especially in mental disorders and addictions and development of new drug treatments. There has been revolutionary advances in brain imaging with developments in functional Magnetic Resonance Imaging (fMRI) and Positron Emission Tomography (PET) leading to new insights into attention, emotions, memory and disorders like depression and Schizophrenia.

Advances in the understanding of cell death and stem cells have allowed better understanding of effects in injuries to the brain and nervous system and has led to introduction of new treatments in brain injury and stroke. Along with this insights into nerve cell development has provided better understanding of certain childhood conditions with potential clinical applications.

6.2 Psychophysiological Anatomy of the Brain and Nervous System
(Purves et al 2011)
The brain is the control centre comparable to a central processing unit of a computer but only very much more complex. It is situated in the head well protected by the hard skull. The brain is the part of the Central Nervous System (CNS) along with the spinal cord. The spinal cord is well protected within the vertebral column. Brain and spinal cord are covered on the outside by a membrane complex called the meninges. There are spaces inside the brain called ventricles and the spinal cord called spinal canal which contain the cerebro-spinal fluid (CSF) which nourishes the tissues.

![Figure 1: Overview of the Brain and Nervous System Anatomy](Modified from Courtesy: stlukeshealthsystem.org)

The nerves coming out of the brain and the spinal cord and distributed to every part of the body in a complex network forms the Peripheral Nervous System (PNS). These carry sensations or sensory impulses from the various organs including skin, muscles, and internal organs to the CNS and motor impulses from the CNS to the target organs to facilitate the required action or function.
The Autonomic Nervous System (ANS) regulates all automatic functions of the different organ systems to maintain homeostasis. ANS is divided into the Sympathetic Nervous System (SNS) and Parasympathetic Nervous System (PNS). These together maintain the balance in the internal organs, and functions like temperature regulation, hormonal balance, metabolism, etc.

The SNS mobilizes energy and resources especially during stress and is responsible for the Stress Response. The PNS conserves energy and resources and is responsible for the Relaxation Response. Many mind-body medicine techniques including yoga have effects on modifying the function of the ANS so that the sympathetic flow is reduced and the parasympathetic flow is enhanced, restoring the balance or homeostasis in the different internal organ systems which may be disturbed in various pathological states thus facilitating healing.

The human brain has a large portion called the cerebrum which is associated with high order functions affecting behaviours, thinking and emotions. It is divided into two halves, the right and left hemispheres by a fibre bundle called the corpus callosum through which communication between the two
hemispheres is established. The outer part of the cerebrum is called the cerebral cortex and is also referred to as the grey matter. It is folded multiple times giving a wrinkled appearance. This produces grooves called sulci (singular: sulcus) and mounds called gyri (singular: gyrus).

The cerebral cortex is arbitrarily divided into regions based on their functions. This is called cortical mapping. The Frontal Lobe is situated in the front and underlies higher mental functions of thinking and voluntary motor coordination. The Occipital Lobe is situated at the back and aids in visual processing. The Parietal Lobe on the side and upper part is responsible for coordination of sensing and action and language function. The Temporal Lobe is on the side and lower aspect and responsible for behaviours, emotions and speech. Cerebellum is mainly responsible for balance and muscle coordination. In the brain stem are situated very important control centres for breathing, blood pressure, heart beat, temperature control and swallowing.

6.3 The Nerve Cell or Neuron and Neurotransmission

(Purves et al 2011, Neuroscience 2012)

The nerve cell or neuron is the basic working unit of the brain and nervous system. There can be anywhere between one billion to one trillion neurons in the brain. They are the main systems processing and transmitting information to all other cells of the body. Each neuron comprises of a cell body with a central nucleus and a long extended fibre called an axon which carries electrical impulses from the cell body to distant regions giving rise to further smaller extentions and ending as axon terminals.
The axon is covered by an insulating sheath called the *myelin sheath* which speeds up the transmission of electrical nerve impulses. The neuron has other cellular extensions like the branches of a tree, called *dendrites* that receive messages from other neurons. The point of contact where a terminal of one neuron communicates with another neuron is called a *synapse*.

Nerve impulses are responsible for opening or closing channels in the cell membrane of the neuron called *ion channels* which allow charged particles called *ions* to move in and out of the cells. This produces voltage changes across the cell membrane. The difference in the electrical charge between inside and outside is responsible for the nerve to fire nerve impulse. When a nerve impulse begins, there is a change in the membrane potential called the *action potential*. This travels along the axon and at great speeds and cause the release at the nerve terminal of chemical messengers called *neurotransmitters*. This is responsible for changes in the target cells of organs like contraction of a muscle, control of heart beat, release of a hormone or an enzyme, etc.

Several neurotransmitters have been discovered and still being discovered. It is important that these neurotransmitters are regulated so that they contribute...
to overall equilibrium of the human organism. Any increase or decrease leads to dysregulation which can happen in diseases or created through chemical substances or drugs.

*Acetylcholine* is an important neurotransmitter involved in several functions. It is responsible for movement and action in that it allows the muscles to contract. It is also responsible for the control of heart beat. It is an important neurotransmitter in the brain critically involved in attention, memory and sleep. This may importantly be influenced by yoga practices improving its transmission.

*Amino Acids*, which are important building blocks of proteins in the body are also important as neurotransmitters in the body and the brain. Amino Acid neurotransmitters in the brain called *Glutamate* and *Aspartate* are excitatory and act on neuroreceptors called *N-Methyl D-Aspartate (NMDA)*. They increase activity and are implicated in learning and memory and in development. Excess can lead to cell damage and even cell death as in stroke and trauma. *Glycine* and *Gamma-Amino-Butyric Acid (GABA)* are inhibitory amino acids and inhibit or prevent activity. Drugs like sedatives and antiepileptic drugs act on these neurotransmitter systems. A dysfunction is seen in Huntington’s disease.

*Catecholamine* is another group of neurotransmitters. *Dopamine* belongs to this category and is present in the brain helping in movement, emotion and cognition, pleasure regulation and hormone release of the Pituitary gland. Dysregulation of Dopamine is seen in Parkinson’s disease and Schizophrenia and illicit drug abuse. Norepinephrine is a catecholamine which helps in memory and learning and control of heart rate and blood pressure. It is released as part of the stress response. Dysregulation is seen in Alzheimer’s disease, Parkinson’s disease and Korsakoff’s disease due to chronic alcoholism. Serotonin is a neurotransmitter present mainly in the brain, gut tissue and platelets. It causes smooth muscle contraction especially in blood vessels where it is involved in blood pressure regulation. It is implicated in the brain in sleep and mood regulation and in depression and anxiety.
Opioid neurotransmitters are peptides, which are also made up of amino acids but smaller than proteins. Encephalin and Endorphin are opioids which regulate pain and to some extent sleep and are produced in the brain and spinal cord. They are released during acute stress and trauma which allows the organism to numb the immediate pain and postpone the pain. They may also be released during vigorous exercises. Substance P is an opioid responsible for burning sensation.

Trophic Factors are small protein neurotransmitters produced by brain cells. They are involved in development of nervous tissue and gene expression and are still being studied as there may be potential therapeutic applications in developmental disorders and degenerative disorders. Hormones are also produced and regulated by the brain. Hormones are produced by the endocrine system and also various other organs like pancreas, kidneys and heart.

The brain derived hormones critically regulate release or inhibition of other hormones and regulate basic behavioural activities like emotions, stress response and bodily functions, sex, energy use, growth and metabolism. Gases like Nitric Oxide and Carbon Monoxide can also act as neurotransmitters and act by diffusion. Nitric Oxide regulates intracellular second messenger molecule called Cyclic Guanosine Mono-Phosphate (cGMP) in the brain. Prostaglandins and Endocannabinoids are lipid messengers associated with fever, pain response in inflammation and in stress reactions. The neurotransmitters act at the level of the cell membrane and are hence called first messengers. Further transmission of information inside the cell happens through substances called second messengers. Cyclic Adenosine Monophosphate (cAMP) is a second messenger produced from Adenosine Triphosphate (ATP) which has a variety of facilitating effects inside the nerve cell.

This intricate system of communication in the nervous system is vital and develops by the third week of gestation in the embryo. This system is very flexible and makes the organism adaptable to different situations and environments. Recent research in Mind-Body Medicine (MBM) which incorporates principles and practice of yoga, have effects on several of these
neurotransmitter and second messenger systems helping to correct dysregulation and restore balance.

6.4 Development of the Brain and Nervous System
(Purves et al 2011, Neuroscience 2012)

Neurodevelopment is the term used to describe the development of the brain’s functional pathways influencing the various abilities and skills of the brain. Any hindrance to the development can occur due to various factors during the prenatal, natal and postnatal periods giving rise to neurodevelopmental disorders like learning disabilities, autism, cerebral palsy, specific learning disabilities, speech and language deficits, and sensory integration dysfunction and other neurodevelopmental disorders which includes certain severe mental disorders like schizophrenia.

Early intervention utilizing the principles of neuroplasticity can make a significant difference in terms of improvement in neurodevelopment and functions. The foundation for neurodevelopment is laid in the very early embryonic development of the nerve cells which is a crucial period in the life of the developing baby.

Nerve cell and brain formation begins in the embryo inside the womb. During the very early stage of development of the embryo, three cell layers appear called Ectoderm, Mesoderm and Endoderm. The mesoderm releases certain signalling molecules that kick starts the process of differentiation of the cell layers into different tissues and organ systems by turning on or turning off of genes. This process is called induction and neural induction happens in the ectoderm. Different neural cell lines form of which the important are neurons and neuroglia which are supporting and nourishing cells for the neurons.

Interestingly, skin too is derived from the ectoderm. Following neural induction, cell migration happens leading to formation and development of the different parts of the nervous system. Migration is a very delicate process. Any discrepancy in the migration in the form of effects of chemicals like drugs or
alcohol can lead to abnormal development of the nervous system leading to disorders later in the foetus and in the child. Mental retardation and epilepsy are examples. Following migration of the cells to their designated locations, they make interconnections in a complicated and intricate network through the axons and the dendrites.

Specialization of structures and functions happen. There is a powerful interplay of genes and the environment influencing the development and growth of the nervous system and so the individual. There are critical periods in the postnatal period i.e. after birth of the baby when important cues and stimulation have to occur that contribute to the development of various sensory and motor functions. Therefore development is a continuous process that continues not only during childhood and adolescence but also well into adulthood and even old age. The brain and nervous tissue modify and adapt continuously to challenges and changes in the environment by the process of neuroplasticity. Neuroplasticity produces sometimes desirable and sometimes undesirable effects and behaviours depending on the type of stimulus from the environment.

Certain environmental exposures are critical during certain sensitive periods for normal maturation to occur. For example, there is a set of conditions called sensory processing integration dysfunction where there is abnormal are reduced sensory integration during maturation leading to reduced or abnormal development of processing of the different sensations like vision, hearing, touch, taste and smell which can lead to behavioural and emotional problems in the child. Certain of these changes which have occurred in critical periods of neuroplastic development can be difficult to change or overcome leading to disability and requiring special rehabilitation measures.

Recent research in Mind-Body Medicine focus on teaching children simple techniques derived from yoga and meditation practices to improve learning, attention, memory, sensory processing, motor coordination, etc. in order to treat or prevent many developmental disorders of childhood.

**6.5 Neuroscience of Stress and Chronic Stress**
Stress is defined as a non-specific response of an organism to any demand or pressure from the environment. It is a state of psychophysiological arousal. Stress response is a set of psychophysiological reactions to any event perceived as a threat. This threat can be to the body or the mind or ego threat. The body-mind system then activates defence mechanisms to counter the threat either by running away or by withdrawing or by aggressing. It is a basic instinctual survival response. This is called the Flight-Freeze-Fight Response or simply the Flight-Fight Response. The intensity of stress is dependent on perception and appraisal. If a particular situation is perceived and appraised as exceeding the capacity or resources of the individual to handle, then stress is experienced.

When in daily life our expectations are high or unrealistic, this may cause us to experience excessive stress. A stress response is usually triggered by an event which may be outside or inside. Outside triggers may be in relationships or the environment or unpredictable events. Inside triggers may be unhealthy habits, negative attitudes, perfectionism, unreasonable expectations or irresponsible behaviours. Once a situation is perceived and appraised as a threat, the stress response is activated in the brain.

Figure 4: Stress Response and HPA Axis
(Modified from Courtesy: dericbownds.net)
The Hypothalamo-Pituitary Adrenal (HPA) axis initiates an energy mobilization mechanism. Hypothalamus is a part of the Limbic System which is the emotional centre of the brain. A surge of feeling is experienced which may be fear or depression or anger readying the organism for the flight-freeze-fight response.

Pituitary releases the hormone Adreno-Cortico-Trophic Hormone (ACTH). This stimulates the adrenal gland to release the stress hormones, cortisol and adrenalin or epinephrine and nor-adrenalin or norepinephrine. Simultaneously the sympathetic nervous system (SNS), part of the autonomic nervous system (ANS) is activated. These produce various physical and mental symptoms due to the action of the combined effect of the stress hormones and the sympathetic activation on various other organs and organ systems in the body.

Physical symptoms can be tension, headache, dizziness, blurring of vision, passing out or loss of consciousness or syncope, nausea and vomiting, dryness of mouth, altered breathing, palpitations, tightness in the chest, flushing, sweating, shaking or tremors, unsteadiness, tingling and numbness - ‘pins and needles’ in the hands and legs, cold clammy palms, body aches, weakness/fatigue, abdominal discomfort/‘butterflies in the stomach’, urine urgency/frequency, and urge to evacuate bowels/diarrhoea.

The mental symptoms can be mental tension, fear and anxiety or nervousness, irritability or anger and hostility, sadness or depression, foreboding sense of doom, uncertainty feelings, helplessness, self-blame, hopelessness, low self-esteem, worthlessness, inadequacy, and low self-confidence.
The immune system can also be affected and the inflammation response can also be triggered. What symptoms are experienced is dependent of the perception and appraisal which is based on attitudes and biological make-up of the individual. Not all symptoms occur. The duration of some of the symptoms may be very short and disappear in a few seconds whereas some symptoms can last several minutes or even a few days. Again there are individual variations.

The psychophysiological states of the stress response are useful in certain situations when there a real threat and danger and the organism has to either escape or fight in order to protect itself and to survive. Once the threat is gone or the perception of threat is diminished and the feeling of safety is restored, there is no more arousal and the stress response ceases. The opposite response is called the relaxation response and is governed by the parasympathetic nervous system (PNS).
Mind-Body Medicine techniques and yoga stimulate or activate the relaxation response and hence help restore balance or prevent the damaging effects of the stress response and hence can stimulate healing.

In the complex and modern environment and busy lifestyle with unnatural modes of being and living, many times against nature, the stress response may be activated unreasonably and frequently. An example is chronic pain in work related repetitive strain injury in busy professionals using computers excessively and added strained lifestyle. Here pain is triggered without any tissue damage due to over-sensitivity and de-conditioning of neuro-musculo-skeletal system mainly and also the mind-body system as a whole, leading to maladaptive behaviours and chronic stress. This activates the stress cycle which can become a habitual vicious cycle leading to more long term effects.

Figure 6: The Stress Cycle (Modified from Courtesy: Kabat-Zinn 2013)
Human behaviour is a combination of feelings, thinking and actions. Behaviours are motivated through experience and learning. Sets of behaviours learnt and repeated over time become habits leading to conditioning of the mind-body system to think, feel and act in particular ways in particular situations. Thus several habits or conditioning of the mind-body system are acquired many of which may be not conscious and therefore incorrect and against nature. Such conditioning may have occurred as a result of trying to avoid negative feeling states such as distress and discomfort due to physical or mental pain or anticipation of such events.

The complexity of modern lifestyle has led to chronic stress giving rise to lifestyle disease. In modern healthcare chronic stress is dubbed ‘the mother of all modern diseases’. The lifestyle disease are heart disease, hypertension and cardiovascular diseases, diabetes, osteoarthritis, thyroid disease, ulcer and acid peptic disease, irritable bowel syndrome (IBS), Rheumatic disease, headaches and migraine, depression and anxiety disorders and psychosomatic disorders, alcohol and other substance-use disorders, sexual dysfunction and infertility, cognitive impairment and the progression of several other diseases including cancer.
6.6 Neuroscience of Coping and the Relaxation Response


Stress starts with perception of situations and events whether external or internal. One may not be able to change the situation or event but one can change the perception. Perception requires becoming aware. Becoming aware requires paying attention. Mind-Body practices including yoga can help the process of enhancing attention and becoming more aware and mindful. This enhances our ability to choose. In attention training one trains the mind to choose one thought over the other. Thus habitual conditioning that has happened by default, can now be corrected by becoming aware of the maladaptive nature of the thoughts which may be influencing the feelings and actions and so the behaviours.
Yoga also has effects on the HPA axis and the sympathetic nervous system in diminishing its activation and enhancing the activation of the parasympathetic nervous system thus triggering the relaxation response. Relaxation response brings rest and calmness to the whole body-mind system. Repeated activation of the relaxation response has been seen to have longer term beneficial effects on overall stress levels and stress management. The body-mind system is re-conditioned by activation of the virtuous cycle. The earlier maladaptive conditioning and associated behaviours are inhibited or faded or their power is reduced and adaptive and health enhancing behaviours are established.

Stress response which is associated with emotional arousal and physical symptoms may be appropriate in some situations and may be inappropriate at other times. The way we handle them is dependent on how aware or mindful we are of them. Our responses are also dependent on the state of mind we are in at that moment. Practice of yoga can change the state of mind. Awareness gives better clarity of thinking and analysis and hence better judgement. This can also have effects on attitudes as we are able to think through situations with better clarity.

It is said that ‘attitude is everything in life’. Changing attitude can change our responses. Attitudes are formed right from childhood and can influence health and quality of life. These are formed as habits and is moulded by experiences and biological characteristics. Attitudes influence emotions and so the responses to events and situations. Toxic or negative habitual emotions and responses can negatively affect all bodily systems including the nervous system, cardiovascular system, digestive system, respiratory system, immune system among others.

Brain imaging and electrophysiological studies have shown that training in attention, awareness, mindfulness and compassion, produce visible changes in the brain’s higher centres of control in the prefrontal cortex and at the same time inhibition of activation of the stress response system regulated by amygdala and the limbic system controlling emotions. Repeated yoga based
mind-body medicine practice can induce more lasting changes as a result of positive neuroplasticity in the brain and neural circuitries leading to perceivable changes in attitudes and wellbeing leading to improved health state and quality of life.

One way of measuring improved health state is determining the autonomic nervous system integrity and health. This can be known by measuring the Heart Rate Variability (HRV). Heart Rate Variability (HRV) is the beat to beat variability of the heart rate. Greater the variability more efficient is the function of the autonomic nervous system. Yoga and related mind-body medicine practices including asana, pranayama and dhyana or meditation, has been seen to improve the HRV which can be used as a simple measurement and also as a feedback to monitor progress during practice. This is also widely used in research.

The HRV is particularly indicative of the Vagus Nerve tone or balance. The Vagus Nerve is the tenth cranial nerve. There are 12 cranial nerves in the nervous system. Vagus in Greek means wanderer and is called so as the nerve supplies distant organs way down in the chest and the abdomen. The parasympathetic flow and innervation is through the Vagus Nerve. It is responsible for the normal functioning of several organ systems. The Vagus nerve helps in the relaxation of the organs and allows it to ‘calm down’ or rest. It regulates the metabolism and modulates the immune system. The Vagus also has important neuropsychological functions. It is important in perception and awareness, intuition, empathy and compassion and in social bonding.
This parasympathetic nervous system function in positive emotions, attitudes and pro-social behaviours is connected to higher brain activities. Functional Magnetic Resonance Imaging (fMRI) studies of people showing approach related positive emotions whose personality traits are characterized by high alertness, enthusiasm, high levels of energy, persistence in reaching their goal show distinct activation patterns in the left prefrontal cortex. Whereas people with depression show activation patterns in the right prefrontal cortex. Long-term follow up studies of infants and children who show left sided prefrontal activation patterns have seen to grow up into more social and warm individuals.

More recent studies in long term practitioners of meditation and yoga especially those involving contemplative practices of dhyana based on the yama aspect of Patanjali ashtanga yoga involve developing focussed attention, mindfulness and meditation involving deliberate cultivation of compassion, loving kindness and other ethical qualities. These have shown establishment of similar patterns of left sided prefrontal activation and reduction or inhibition of activation in amygdala and other limbic components along with activation of the
parasympathetic outflow through the Vagus nerve. This can be sustained through practice as the mind-brain system becomes re-conditioned through neuroplastic changes in the underlying neuronal function and neural circuitry.

6.7 Psychoneuroimmunology

An intricate system of interaction and integrated function exists between the mind, the nervous system, endocrine or hormone system and the immune system in health and disease. The scientific study of these associations and their clinical applications in called Psychoneuroimmunology (PNI).

Our body’s first line of defence against any infection or trauma or injury is a ‘non-specific immune response’ called the sickness response. This triggers a series of physiological and psychological events. These events include fever, tiredness, changes in liver metabolism, decreased food intake, decreased curiosity and exploration, decreased pleasurable activities, withdrawal and...
increased anxiety. This is associated with the activation of the stress response through the HPA axis with the release of cortisol hormones.

The response is biologically innate in order to mobilize energy to fight infection and at the same time conserve energy through changes in behaviour. This response is triggered by signals from the hypothalamus. This induces the immune system to mobilize immune cells called macrophages at the site of pathology in the form of infection or trauma. Macrophages release molecules called pro-inflammatory cytokines. These are Interleukin-1 (IL-1), Interleukin-6 (IL-6) and Tumour Necrosis Factor alpha (TNF-α). These molecules bind to receptors in the neurotransmitter synapses in the paraganglia of the Vagus Nerve. From here the signals reach the brain. In response to these signals, the brain produces Interleukin-1 which triggers the sickness response. Signals are sent back via a feedback loop system that further activates the immune cells.

The stress response and immune response act in synergy influencing each other and exaggerating each other’s responses. This can cause sensitization of the shared neural circuits. Thus chronic stress causes a dysregulation of this combined psycho-neuro-endocrine-immune system which can lead to disease.

The pro-inflammatory cytokines are also seen to contribute to the pathology of several non-communicable diseases including cardiac disease, diabetes mellitus, inflammatory conditions in mouth and teeth, osteoporosis, Alzheimer’s disease, metabolic syndrome and obesity, debility, frailty and functional decline related to age and risk factor for cancer.

Research specifically directed to look at the effect of yoga and mind-body medicine practices has shown to reduce not only the stress response, but improvement of vagal tone, with increased HRV and reduction in the pro-inflammatory cytokines in the circulating blood thus leading to improvement in the immune function. The implications are that this reduces the burden of contribution to the aetiology of pathological conditions thus helping in the healing process.
Recent psychoneuroimmunoendocrinology research suggest that yoga as a holistic practice and adopted as a way of life in all its aspects which would include the limbs of the *ashtanga yoga* potentially has the benefit of being a preventive medicine approach to reducing disease burden and improved quality of life not only in the individual but also in the community if applied and incorporated into public health programs.

### 6.8 Cognitive Neuroscience

Suffering is a state of the mind. It is an experience of distress which is associated with emotions. Emotions are processed in a complex circuitry in the brain called the limbic system. The limbic system does not have a specific location but more a conceptualization integrating neurophysiological and psychoanalytical understanding of drives, emotions, learning and behaviour.

The limbic system comprises mainly the cingulate gyri and the parahippocampal gyri and is defined around the hippocampus or hippocampal formation in the brain. Hippocampus is the centre of sensory integration and considered as the seat of emotional experience. Hippocampus projects into the hypothalamus which can be conceptualized as an organ of emotional expression with its connections further down to the autonomic nervous system and endocrine system. The core of the limbic system is formed by the medial forebrain bundle which carries ascending and descending nerve tracts connecting orbitomesiofrontal cortices of the two hemispheres, the septal...
nuclei, the amygdalae and the hippocampi. The connections also go down to nuclei in the midbrain and the pons further down anatomically.

The cingulate system is associated with several neurocognitive abilities including the ability to shift attention, helping the mind to move from one idea to another, adaptability and flexibility allowing the mind to go with the flow, allowing the mind to see options, ability to feel safe and secure and ability to cooperate. The cingulate system has connections further higher up with higher brain functional systems particularly the prefrontal cortex.

The neurocognitive functions associated with the prefrontal cortex are conscious thought, attention span, concentration, organization, problem solving, impulse control with self-monitoring and self-supervision, perseverance, judgement, critical thinking, forward thinking, decision making, ability to feel and express feelings, empathy and compassion. These are higher functions in terms of evolutionary cognitive psychology. These capacities are most well developed in the human beings as compared to the lower animals. It was believed earlier that these areas and functions did not influence the autonomic nervous system. But this has now been proven to be not so and indeed conscious thoughts do influence lower sub-cortical systems that are directly connected to the autonomic nervous system and are able to influence them in negative or positive ways. In fact, mind-body medicine practices are based on the influence of higher neurocognitive processes and systems having an influence on lower subcortical, autonomic and endocrine functions producing there beneficial effects.

The prefrontal cortex along with other circuitry including the cingulate system are developmentally of recent evolutionary origin and hence called the neocortex. It is said that “the neocortex sits astride the limbic system like a rider on a horse without reins”. When there is a disengagement between the neocortical system and the sub-cortical limbic system, then there is disinhibition and the stress response is active. This can become chronic if unattended leading to development of disease. Reengagement and integration can be achieved mental psychophysical efforts that is possible due to neuroplasticity.
of the brain. In terms of the analogy of the horse and rider, it is the training of the horse and skilling of the rider to lead the horse in the right direction which is the path of health and wellbeing. Yoga is one such practice of mind-body medicine that has now a sound scientific basis to help achieve this.

Figure 13: Frontal Cortex and Limbic System Relationship During Stress
(Based on Courtesy: The Effect of Stress and the Brain on slideshare.net)

The emotional mind operates through association. This is called primary process thinking. Events are perceived through a bias which is centred on the self. In primary process thinking there is a tendency to look for symbolic significance. There is what is called ‘loose associations’. These determine the direction of flow of thinking which is like the analogy of the rider sitting on the horse without reins. Hence there is a disengaged state between the higher frontal control and the sub-cortical limbic processes. In primary process thinking one object may symbolize or stand for another and one feeling may displace and stand for another feeling. There may be no sense of wholeness and the whole may be condensed into its component parts. There may be no logic or
rationale in the cause-effect sequence with assumptions predominating the thinking. There may be no coherence of time. Primary process thinking can make the person react to the present as if it were the past through links to memory.

Deep rooted and maladaptive patterns of emotions can indeed be reshaped. This can be achieved through proper mental and thought training and management. Through such training processes, that is possible with Cognitive Behaviour Therapy (CBT) and other mind-body based therapies including Mindfulness Based Cognitive Therapy (MBCT), Mindfulness Based Cognitive Behaviour Therapy (MBCBT), Mindfulness Based Stress Reduction (MBSR) programs and yoga based programs, though the tendency for the emotional reaction to be triggered may not disappear completely, there can be changes in the responses that one makes once the emotional reactions are triggered.

The default network is associated with negative automatic thoughts which may be part of the stream of self-talk that run through a person’s mind. Negative automatic thoughts can be activated by strong negative feelings that can compel one to respond negatively or behave in socially undesirable ways. For example, if angry feelings are triggered by some event, one is compelled to react angrily and this can generate angry thoughts and bring on more angry automatic thoughts from memory. Similarly, sad feelings can generate sad thoughts and one’s behaviour can reflect this state of mind. It can be seen many times that many of these thoughts are not based on reason or logic. They are irrational and can be based on misperceptions, misconceptions, faulty assumptions and irrational beliefs that may have developed based on inadequate information or misinformation. When these are left unexamined or unchallenged or unquestioned and remains unaware to one consciousness then faulty conditioning can happen which then become habitual.

A habit or conditioning once established is hard to break. These have to be made aware, brought into conscious mind by exploring past memories, the misconceptions need to be challenged and beliefs corrected, the doubts need to be cleared and the negative self-talk needs to be replaced with positive self-
talk. This can take place in cognitive behaviour based and mindfulness based therapies.

![Image of the Cognitive Behaviour Model]

Figure 14: The Cognitive Behaviour Model (illustrated by author)

When one’s life is visited by suffering due to any reason which can be disease, chronic pain, trauma, illness, disability or prolonged stress, one experiences negative feelings and affect which can often be quite intense. These emotions are in the form of fear or excessive anxiety, anger or hostility and/or depression or unhappiness or sadness. These strong feelings and associated cognitions can have quite a profound impact on one’s life. These emotions can have a very strong influence on how one responds which are expressed through words and actions or behaviours. In turn these negative mental states can affect one’s self-worth, self-respect or self-esteem and self-confidence which in turn can affect relationships and social-occupational functioning and quality of life.

These mental states can in turn use up a lot of energy reserves thus reducing the person’s resilience to suffering. For many it can be often very difficult to even acknowledge that such intense negative feelings exist as it may be
pushed into the unconscious through the ego defence mechanism of repression. There is a collective social and cultural expectation to be seen as emotionally strong and not being allowed to admitting negative feelings which may be seen as a ‘mental weakness’. This attitude has to be tackled at its root which may be deep in the psyche.

Ego defences are mechanisms of psychological defence that become operational when the psyche perceives threat to its existence. These are psychological conceptualizations and come under the field of ego psychology. Defences can be immature and mature. Immature defences are negative and can contribute to or aggravate psychic suffering and can lead to psychopathology. Here sub-cortical reactionary fight-freeze-flight responses are operational as they have disengaged from higher cortical processes. Mature defences are healthy and are positive which lead to understanding, growth, improved self-esteem, self-confidence and move towards self-actualization. It is training to move upward on the hierarchy of needs. The hierarchy of needs concept was first put forth by psychologist Abram Maslow and are called Maslow’s Hierarchy of Needs.

The physical and safety needs are called the D-Needs or deficiency needs. Love and belongingness needs, esteem needs and self-actualization are called being needs or B-needs. Every human being has a desire and has the capacity to go up the hierarchy of needs through self-effort. Due to various factors in the
self, environment and society individuals have a tendency to fluctuate between the different levels.

Originally Maslow conceptualized five levels of this hierarchy. (1) Biological and physiological needs which include food, water, air, shelter, warmth, sleep, sex, etc. (2) Safety needs including security and protection, law and order, and stability. (3) Love and belongingness needs include trust, acceptance, and friendship, affiliation, giving and receiving affection, intimacy and love (4) Esteem needs self-esteem, independence, mastery, achievement, prestige and responsibility (5) Self-actualization, which is the peak of self-achievement and personal growth.

In later work on the needs hierarchy, three other levels have been introduced. After esteem needs, cognitive needs are present, which include curiosity, exploration, need for meaning, knowledge and understanding. After this is the level of aesthetic needs which involves appreciation of and search for balance, organization, beauty, etc. A level beyond self-actualization has been introduced called self-transcendence which is a selfless aspect of human achievement of altruism, helping others achieve self-actualization, wisdom and spirituality. This resonates with the self-realization or equanimity or true wisdom variously termed as nirvana, samadhi, etc., in the yoga and Veda traditions of India.

Awareness and mindfulness along with self-empowerment through mind-body interventions including yoga can activate mature defence mechanisms and recondition the organism into healthy ways of being and living thus contributing to overall health, wellness and improved quality of life.

There is a welcome shift in current research in neuropsychology from studying pathological states and disorders to positive states of the mind and how they influence overall health and wellness, promoting wellbeing and decreasing the susceptibility to illness and developing resilience. The research is directed towards processes and techniques that affect the higher neurocognitive processes and produce observable changes in the regions and systems in the brain like the prefrontal cortex and cingulate systems and in turn positively
influencing the limbic system. The strongest evidence is emerging out of the studies of mind body medicine.

6.9 Mind-Body Medicine

Mind-body medicine is a recent area of clinical medicine that applies to interactions between the body, behavioural factors, emotions, cognitive processes, social factors and spirituality and the ways in which they affect health and wellbeing. There is an emphasis on self-knowledge and self-care and are considered as important capacities that can be enhanced through specific processes and practices. One’s thinking and behaviour can have a significant impact on one’s life, physical health, mental health and the capacity to recover from ill-health and injury or trauma, both physical and mental and social and occupational functioning. In mind body medicine there is a paradigm shift from a biological model of health to a bio-psycho-social model or even a bio-psycho-socio-spiritual model of health. Mind-body medicine is not seen as a replacement of conventional medical treatment but as a vitally important compliment to it. Mind-Body Medicine (MBM) has become an important stream of study and therapeutics in several high ranking universities and teaching hospitals in the USA, Europe and other countries.

Mind-Body Medicine now has good and robust research evidence which is growing. Mind-Body Medicine approach incorporates lifestyle changes. Lifestyle changes can be transformative and act at very deep levels physically and mentally. At the genetic level there is enhanced functioning of the telomerase enzyme which is responsible for the lengthening of telomeres in the chromosomes. Telomeres are present at the ends of the chromosomes. The length of the telomere is directly proportional to health and aging. These changes have been seen in studies in chronic diseases and cancer with improved telomere length being activated almost immediately on incorporating lifestyle changes with positive outcomes on health and healing of the condition. Lifestyle changes is part of the yama or observances and niyama or disciplines of ashtanga yoga practice of Patanjali Yoga Sutras.
One important component of mind-body medicine lifestyle intervention includes dietary changes. The recommended and scientifically examined and proven diet is predominantly vegetarian, low fat, low salt, high fibre and natural diet. This diet can reduce risk and even heal chronic inflammation, detoxify and rejuvenate the cells. This diet is close to the yoga concept of satvic diet. Satvic diet is recommended as a health giving or healing diet in yoga and Ayurveda. This forms part of the three-fold diet. The second type of diet is rajasic, which is intermediate and can be stimulating and recommended in moderation but to be avoided during illness. The third form is called tamsic, which is unhealthy and may be toxic and is a diet to be avoided under all circumstances.

Mindful eating is paying attention to what we eat so that we chose the right health giving food, pay attention to where we eat, and how we eat in terms of our state of mind while eating, eating slowly and consciously so that the food is digested and assimilated in a way that is energy enhancing and healing. Mindful eating is part of mindfulness based therapies and has proved effective in several conditions like cardiovascular diseases, metabolic diseases, autoimmune diseases, endocrine disorders, inflammatory conditions, obesity, depression, eating disorders, etc.

Physical culture in the form of stretching and flexibility training, breathing exercise, mindfulness, meditation, productive work and social support. These are all aspects of yoga as asana, pranayama, dharana (attentiveness), dhyana, karmayoga (work as worship or duty without expectation) and satsangh (association with goodness or keeping good company). These are concepts which are part of yoga principles and practices. Other mind body techniques are hypnosis, guided imagery, cognitive behaviour therapy (CBT), biofeedback, Tai Chi and Qi Gong, Western adaptation of Hatha Yoga and mindfulness. Mind-body medicine scientific studies are increasingly bringing together the researchers in cognitive psychology, neurophysiology, psychiatry, neurology, molecular neurobiology, and several other disciplines.

Guided imagery and auto-hypnosis use imagination and the power of suggestion as healing tools. Techniques of guided imagery and auto-hypnosis
can be comparable to the *pratyahara* or sensory regulation of ashtanga yoga practice.

In guided imagery the imagination is guided to associate with positive and neutral objects engaging with all sensory modalities of vision, hearing, taste, smell and tactile sensitivity. For example, the patient is instructed to sit comfortably with eyes closed and imagine that he or she is sitting under a fruit tree on the bank of a river and try to fully experience that scenario in the mind by seeing themselves being there, seeing the river, hearing the river and the wind and birds singing in the tree, smelling and tasting the fruit and feeling the breeze and the grass beneath them. This pleasant scenario helps activate the parasympathetic nervous system bring about relaxation.

Auto-hypnosis uses techniques to make oneself feel relaxed and enter into a hypnotic trance state and a strong positive post-hypnotic suggestion is to be self-administered whereby the patient is able to feel confident at reducing negative responses after the session.

There is a surge in interest in mindfulness meditation which has been adapted from Buddhist *vipassana* practice. This can be further traced back to the dhyana practice of yoga. In fact the practice of Japanese *Zen* is derived from the Chinese *Chan* which is an adaptation of the Sanskrit *dhyana* or *dhyan*. Mindfulness meditation is the technique or process of cultivating non-judgemental awareness of experiences from moment to moment. It is training the attention and awareness to be in the present. Beneficial effects of mindfulness meditation has been scientifically proven in several physical and mental conditions. The concept of mindfulness runs throughout the yoga sutra of Patanjali.

Mindfulness exerts its effects through several components of cognitive neuropsychological functioning. These are: (1) Attentional Regulation (2) Body Awareness (3) Emotional Regulation (4) Perspective Change on self. In mindfulness there is a reappraisal of feelings, exposure, extinction and reconsolidation of affect. Structural and functional neuroimaging studies
provide empirical support and evidence supporting the neurocognitive mechanisms of mindfulness. The practice of mindfulness has shown to produce neuroplastic changes in the anterior cingulate cortex, insula, temporo-parietal junction, frontal-limbic connection network and the structures associated with the default mode network. The four mechanisms are observed to act synergistically thus establishing an enhanced process of self-regulation in the practitioner.

6.10 Contemplative Neuroscience

Science is derived from the Latin scientia meaning knowledge. It is a systematic way of building and organizing knowledge. This is done through observations, and formulating testable explanations and predictions, about the object of study in the universe. Neuro is derived from the Greek neuron meaning nerve. Neuroscience is the scientific study of the nervous system including the brain. The brain cannot be seen separate from the mind. The mind was thought to be a function of the brain. Disturbances in the brain produce disturbances in the mind. The brain influences the mind. But recently cutting edge research using sophisticated technology has shown that the mind can influence the brain.

When we talk of knowledge, we consider it as a thing that can be acquired, possessed and used by the mind. The process or function or activity of the mind that uses knowledge is called thinking. The act of thoughtful observation is called contemplation. It is used synonymously with meditation often. It is seen as a practice in which an individual trains the mind. It may be practiced as an end in itself or as a method leading to positive effects or changes in the individual with the potential of positively affecting others and the environment.

Contemplative neuroscience is the new and emerging field that studies systematically using sophisticated technology the effects of ancient contemplative practices of thousands of years especially prevalent in the East and more specifically originating from India. It uses several scientific methods and computer based instruments to observe and record activities in the brain.
and the nervous system in people engaging in specific contemplative practices of which traditional yoga is gaining attention.

These practices have been proven to produce positive and beneficial health effects on not only the mind but also the body. This provides evidence-based scientific basis for the traditional spiritual techniques of yoga that have been recommended by the ancient sages and yogis as essential for attaining higher states of consciousness, personal development and self-actualization.

The modern concept of health care is transformative care which is holistic and person centred care which takes into consideration physical, mental, social and spiritual factors. The Stress-Vulnerability Diathesis Model of disease puts forth that an individual may be born with certain predispositions or genetic vulnerability to certain diseases but it is not necessary that the disease expresses itself. When there are increased risk factors and contributing factors and the stress burden on the person exceeds the capacity or resilience of the person then the disease manifests itself.

This is explained with the analogy of a bucket. The volume of the bucket is the individual capacity or sensitivity to bear the burden of stress. The water flowing from the tap are the various stresses. As long as the capacity exists there are no symptoms. Once the capacity to bear is exceeded, then physical and mental symptoms express themselves.

![Stress Vulnerability Diathesis Model](image)

**Figure 16: Stress Vulnerability Diathesis Model (Illustrated by author)**
All mind body medicine practices focus on preventive care or enhancing the resilience of the person or the capacity to bear stress so as to reduce the burden of stress on the whole person.

Yoga as a mind-body practice can enhance the protective factors and reduce the risk factors of disease process and thus can be curative and also preventive leading to improved health, wellbeing and quality of life. Transformative care is indeed possible through the practice of *ashtanga yoga* of Patanjali. Ashtanga yoga with all the eight limbs of the practice including *yama* or ethical conduct, *niyama* or disciplines, *asana* or physical culture, *pranayama* or breath work, *pratyahara* or control of senses or mindfulness, *dharana* or concentration, *dhyana* or meditation and *samadhi* or absorption or equanimity can be seen to address aspects of body, lifestyle, emotional state, social adjustment, spirituality, mental disposition and environment.

6.11 Neuroscience and Spirituality

There is now an increasing acceptance of spirituality in medical science. The neuroscientific correlates of spirituality is considered to be the same as positive
emotions. Positive emotions are a set of selfless and altruistic traits which promote inclusion, warmth and nurture and brings people together. These emotions also facilitate health, wellbeing and enhanced quality of life. The commonly considered positive emotions are hope, joy, trust, gratitude, compassion, forgiveness, love and awe. These feelings allow one to transcend and connect to something that is larger and of a positive and divine nature.

Studies in Mind-Body Medicine especially with meditation have demonstrated that people who practice the techniques regularly report better health, improved wellbeing, and a feeling of sacredness. Though most people had chosen religious symbols as an object of meditation there were several who had chosen neutral or non-religious sounds or images who also reported the feeling of sacredness. The underlying neural substrates for spirituality and positive emotions are in the limbic system and prefrontal cortical connections wherein an integration, cohesion and balance is observed. The commonly used meditation techniques to cultivate positivity are the self-awareness meditation, focussed attention meditation, mindfulness meditation, and loving kindness meditation along with aspects of ashtanga yoga of Patanjali.

Mind-Body Medicine studies in biofeedback measuring and providing feedback of physiological states have used Heart Rate Variability (HRV) and Cardiac Coherence or physiological coherence as measures of the activation of parasympathetic nervous system, and improved vagal tone thus bringing balance in the autonomic nervous system. These are simple measures that can be recorded through non-invasive and harmless devices placed on finger tips or ear lobes. Improved health and wellbeing and positive emotions are reported in practitioners of mind-body techniques who demonstrate higher HRV and high Cardiac Coherence. These are simple clinical tools that can be used in everyday clinical practice to measure and also be used in therapeutic intervention to promote positive emotions and spirituality through mind-body techniques particularly ashtanga yoga of Patanjali.