

Buddhist Meditation and the Brain

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This paper presents theoretical model for understanding Buddhist meditation and experience based on neurological function. The sections elaborate on the biological basis of the brain-mind, providing a theory for consciousness and higher-order processing based on neurological function. From this foundation we examine the hypotheses of the neurological correlates to Buddhist meditation, and by the end arrive at a clearer understanding of the nature and origin of Buddhist insight. [Click here for a PDF version of the paper.](#)

BUDDHIST MEDITATION AND THE BRAIN:

The Neural Basis for Mystical Insight

Introduction.

Bertrand Russell once said that philosophy is the gray area between science and religion. What he may have intimated is the extent to which both philosophy and religion would recede in their authority to explain the events of the world, both in the subjective and objective realms, as science provides an increasingly adequate and demonstrable analysis of the universe. The time is rapidly approaching when the bookends of his statement will come closer and closer together with the growing implausibility of supernatural explanation. While Christianity has traditionally relied on the supernatural to explain its core beliefs, much of Buddhism has lent itself to a practical, experiential and subjectively experimental approach, which shied away from metaphysical speculations.

In regard to its secularism, Buddhism has proved highly compatible with the advancement of science, and may be the first of the major religious practices to be integrated into the mainstream scientific world. This paper is based in the assumption that in time an equally adequate intellectual explanation of Buddhist insight can be achieved using a scientific framework as can be achieved using traditional textual sources. While these two perspective will clearly differ in their language and perspective, it will be increasingly evident that they are referring to the same set of phenomena, one from an objective point of view based in evolutionary and biological analyses and one from a subjective based on the experience of the meditator. It should be noted that both these perspectives can only provide an intellectual or conceptual understanding, and that practice is necessary to obtain experiential insight. A conceptual understanding does not, however, degrade, reduce or explain away the insight of the meditator, but rather aids in affirming it with an unequivocal stamp of truth that transcends the purely personal understanding of the practitioner. As sociologist Marvin Bressler once said on a related subject, the dogged preservation of age-old religious belief systems “…encourages decent men to tremble at the prospect of ‘inconvenient’ findings that may emerge in future scientific research. This unseemly anti-intellectualism is doubly degrading because it is probably unnecessary.”[1] In Buddhism this was never more the case. In this spirit, the following paper is heavily composed of neurobiological theory in relation to Buddhist meditation. It is, however, first and foremost about Buddhism and the experience of insight that results from Buddhist practices.

Most Buddhists would not attribute the insight gained in meditation and practice to a supernatural entity, as some Christians may. This leaves a subset of epistemological possibilities that are compatible with modern science. The question is to what extent is our knowledge and in particular Buddhist insight is tied to the biological medium we are using to “know”? For math, most mathematicians would assert that there is very little, in that while our brains are necessary of course, the mathematics operates as it does regardless of the particular make-up of our brain. There are, however, different types of knowledge, and some are more dependent on the make-up of our brain-mind and the evolutionary forces that shaped it. How we “know” love or desire, for instance, or even the parameters of our sense of Self, are examples of this type of experiential knowledge. These forms of experience would differ greatly if our brain had been shaped by other evolutionary pressures.

The question is whether or not particularly Buddhist insights like the perception of impermanence or that all beings possess Buddha-nature are based on 1) some form of abstract deduction (logic-based for instance) 2) a privileged understanding of the state of basic reality (corresponding to physical reality as some have hypothesized), or 3) the particular process of consciousness itself. Most would probably agree that while Buddhists can of course arrive at the first basis for deduction, it is not primary. The second, while growing increasingly popular with the linkages made to physics, is deceptive. The temptation to conclude that a privileged understanding is achieved through meditation ignores

the embodied state of the understanding. It is assuming that the knowledge functions like deductive or propositional knowledge (a piece of knowledge based on an objective truth sharable by multiple subjects, not necessarily human), and that the understanding can be divorced from its medium (like some would say math can be, in that the math is valid whether used by a brain or by a computer). This paper attempts to show that the insight that results from certain meditation practices, prior to intellectual reflection, is embodied, in that the nature of the knowledge and experience is a direct reflection of the process in which it is embedded. In this manner, meditative insight is the process of consciousness & knowing; itself devoid of the synthetic construct of the Self. This does not, of course, preclude the possibility that the understanding of direct experience is later used to build on or supplement language-based knowledge. While we are just now arriving at an appreciation of this embodied understanding, Buddhists and other mystics have been intensely aware of this distinction for millennia.

The question now arises: how dependent are the insights achieved in Buddhist meditation on our particular brain structure and in what way? Could another organism with high-order processing and language capability, but different emotional modes for instance, still experience Buddhist insight? This paper will argue that Buddhist insight is above all an absence of identification with the Self that evolution has given us. The contents of that Self can and of course do vary, but the absence of the synthetic construction of the Self based on our symbolic world reveals a basic process of consciousness. This assertion seems to resonate well with the notion that all sentient beings possess the Buddha-nature.[2] The next sections elaborate on the biological basis of the brain-mind, providing a theory for consciousness and higher-order processing based on neurological function. From this foundation we will examine the hypotheses of the neurological correlates to Buddhist meditation, and hopefully by the end arrive at a clearer understanding of the nature and origin of Buddhist insight.

The Neural Basis for the Consciousness and the Self

Gerald M. Edelman is a Nobel Laureate currently developing cutting edge models of how consciousness and mental functions arise from neural processes. The centerpiece of his work is the Neuronal Group Selection (NGS) theory.

Selectionist Theory.

At the heart of the NGS theory is the hypothesis that the brain operates as a selectional process, using homeostatic guides and other value systems to select upon a diversity of behaviors and internal states represented in functional neuronal groups. (Edelman, 1992) The value systems are embodied in what has been called the diffusely projecting modulatory system and other structures like the hypothalamus and amygdala that help serve homeostatic functions. (Edelman, 1989; Bear, et al., 1996; Hamann, et al., 1999) The modulatory system is composed of brain areas like the locus coeruleus and the dopaminergic systems that project diffusely to many areas of the brain, and release neurotransmitters that, among other functions, modulate the strengthening or weakening of the synaptic connection patterns associated with the adaptive value of a particular behavior or internal state. (Bear, et al., 1996)

The strengthening and weakening of synaptic connection patterns has also been demonstrated to be dependent on neural activity and the coincidence or degree of synchronization of that activity. The basic observation of one of these strengthening/weakening models, the Bienenstock&Cooper&Munro (BCM) theory, is that the strength of a synaptic connection, and the strength of a pattern of synaptic connections, is dependent on the activity of the synapse or synapses, with more excitation leading to stronger connections. (Rittenhouse, et al., 1999) Synchronized inputs will also strengthen connections, while de-correlated activity may weaken overall connectivity. There is also evidence that a small amount of activity leads to a greater weakening in synaptic connectivity than no activity at all. (Rittenhouse, et al., 1999) LTP and LTD tend to lead to the creation of functional neuronal groups, where a population of neurons becomes strongly connected through the coincident activation associated with a unitary aspect of behavior or experience. (Edelman and Tononi, 2000) The differential amplification of adaptive neuronal groups therefore occurs through the strengthening of synaptic connection patterns, both in activity dependent and in neuromodulator-induced strengthening.

The analogue to a diverse gene pool in natural selection is the tremendous diversity of synaptic connection patterns that arises during brain development and during neurogenesis in the mature brain. The variability is a necessary result of the randomness inherent in neuron migration and cell-process wiring that cannot possibly be directed or instructed by genetics alone. New variability is introduced into the system of the mature brain through the novel patterns of activation between neuronal groups and through neurogenesis in hippocampal and cortical areas, as well as through LTP/LDP-based competition in the case where multiple neuronal groups possess overlapping connectivity. (Edelman and Tononi,

2000; Ericksson, et al., 1998; Gould, et al., 1999)

Connections within and between the neuronal groups associated with a behavior are selectively strengthened based on the input of the value system that evaluates the overall state of the organism as well as by LTP. This leads to a 'memory' of functional activation patterns represented in the strengthened synaptic connectivity. (Edelman, 1989) There is some evidence that the brain continually activates in cycles or reverberations these connection patterns, helping to preserve their relative strength. (Tsodyks, 1999)

'Reentry', defined as the mutual statistical dependence of activity in one neural area based on the activity in another strongly connected area, binds together the various components of behavior and experience as embodied in the active neuronal groups. (Edelman, 1989) Functional and coordinated behavior naturally arises due to the activity-dependent and neuromodulator-dependent processes that helped produce the strengthened patterns of connectivity, which were originally, in most cases, coincident in time and progressively active in sequence. NGS theory proposes the existence of a 'dynamic core', or a unitary but constantly changing pattern of reentrantly connected neuronal groups that are active at any one time. (Edelman and Tononi, 2000) The neuronal groups active in the dynamic core at any point in time are incorporated due to the historically strengthened connectivity with other contemporaneously active groups, and are therefore 'bound together' because of the functional association in the organism's past. Strengthened synaptic connection patterns will not become expressed or made aware of until they are 'bound' into the dynamic core, creating functional reentry with other nervous system areas. (Edelman and Tononi, 2000)

NGS Theory further proposes that primitive consciousness is the process whereby value-neutral sensory and cognitive inputs evoke the activation of strengthened synaptic connection patterns associated with similar inputs from the brain's past. These evoked connection patterns that are not value-neutral, as they are associated, also through strengthened pathways, to the value inputs linked to them in the organism's history, and the various sensory modalities are bound together through real-time and continuous reentrant connectivity. The current value system input then acts upon the evoked activation patterns, driving adaptive behavior from a mixture of past associations and current assessment of the state of the organism. (Edelman, 1989) Primitive consciousness is therefore the tying of a value-neutral scene from reentrantly connected sensory modalities to evoked activation patterns in higher level cortex that place the inputs in the adaptive context of the organism's past experience, while also modifying this activation pattern based on current input from the value system. (Edelman, 1989) The form of the activation pattern is the dynamic core, with more or less strongly connected neuronal groups continually 'entering' and 'exiting' the core of activity.

Higher consciousness, as exhibited in humans, requires linguistic ability and the integration of these symbolic capabilities into the processes of primitive consciousness. Reentrant activity between language centers and the rest of the associational cortex have enabled humans to attach symbolic representations to the brain's own activity patterns, allowing for consolidated reference to inner states, events and objects in the new context of grammatical relations. (Edelman and Tononi, 2000) On the simplest level the association of a symbol with an activation pattern in the brain's conceptual centers is not a process any more complex than that which we have already outlined through reentry and LTP. Grammatical relations may utilize other processes which, neurologically, have yet to be described in any detail.

Neuronal Group Selection (NGS) theory lies in opposition to the model of the brain as a computer. Computer analogies hypothesize that the brain processes bits of encoded information, which can be likened to software, and the basis of mental functioning is the execution of this 'software'. While there are superficial similarities between computers and brains, upon closer scrutiny the analogy breaks down very quickly. A few examples of the problems are the lack of a programmer to assign categories on an unlabeled environment or assign error feedback for behavior; the lack of an observer or homunculi who will read the translation of the 'code' of neurons; lack of intentionality, which is the hallmark of consciousness; and the simple fact that information contained in genes is not enough to specify the precise wiring of the brain as a computer-like model would necessitate.[3]

NGS theory provides a convincing alternative to the computer model by arguing that the brain selects a subset of neural functioning from the huge diversity of potential brain states (synaptic connection patterns) while adaptively matching it to certain value criteria in the absence of a superordinate coordinator. Because NGS theory provides a theory for the operation of consciousness that lacks a superordinate coordinator or homunculus to read 'encoded data', it lends itself immediately to the Buddhist perspective. Buddhist insight has found that there is no essential self; it is an illusion. NGS theory arrives at the same conclusion, one that is necessary to any adequate explanation of the mind. The following processes are foundational to NGS theory, and will lead us directly to the neural basis for meditation and

insight.

COMPONENTS OF NGS THEORY:

The following section individually reviews some of the key ideas in NGS theory in order of development or increasing complexity. Note that some of this material will overlap with what has been presented above.

Developmental Selection.

Formation of neuroanatomy is constrained and guided broadly by genetic expression and chemoaffinity (migration and placement of neurons based on chemical signals from nearby cells). But at the finer levels of synaptic connection there is tremendous diversity that is not programmed or directed by genetics. On the contrary, the state of diversity is the foundation for activity-dependent neuronal selection, where neurons that fire together tend to wire together, thereby leading to the formation of specialized, functional neuronal groupings as observed in sensory and motor maps.[5] Selection occurs in that the formation of certain functional neuronal groups over others in neural space is dependent on the activity of the neurons, which in turn is dependent on the behavior of the organism. An example of this process is the topobiological organization of sensory maps, where nearby locations of sensory input on the finger, for instance, are also nearby in the neural pathways that carry their input and in the structures that process the input.[6] This process has also been described as Hebbian modifications.[7]

Experiential Selection.

Experiential selection overlaps with early development and extends throughout life. It occurs largely within the neuroanatomy created during developmental selection and is based on the activity-dependent strengthening and weakening of connections between neuronal groups. The selectional process is constrained by diffuse projections from the value systems, which favor the strengthening and weakening of synaptic connections under particular pre-set conditions delineated by evolutionary determinants and expressed through the value system[8], corresponding to the diffuse modulatory systems in the brain.[9] Here the strengthening of synaptic connections is indirectly dependent on concurrent firing, in that the value systems concurrently effect those groups firing together. But it is the expression of the value systems that determines when and to what degree patterns of synaptic connection between neuronal groups are strengthened or weakened. A crude example is: if your blood sugar levels drops too low, the value system will strengthen the synaptic connection patterns associated with behavior that raises the blood sugar level, thus ensuring the repetition of this behavior.

Reentry.

Sensorimotor maps and certain other areas of the brain are “massively” connected in parallel and reciprocal circuits. Reentry is the process whereby selection on neuronal groups in one area effects selection on neuronal groups in others and vice versa.[10] This contemporaneous and mutual interaction is the foundation of many of the processes that lead to consciousness.

Perceptual Categorization.

Perceptual categorization is the ability to categorize or isolate salient objects in an unlabeled environment. It is one of the most basic functions of the mind and has been one of the most difficult to adequately explain. NGS theory posits that perceptual categorization occurs when particular sensorimotor patterns (embodied in maps and their reentry) are selected for by value criteria.[11] The strengthening of the synaptic connection patterns underlying these sensorimotor patterns creates behaviors that isolate functional salient characteristics or inputs from the environment at the expense of non-salient inputs. Saliency is determined by the value criteria, which in turn has been evolutionarily selected for. Edelman has been able to construct robots that perceptually categorize based on neuronal group selection and in the absence of programmed error feedback, lending strong evidence to his theories.[12]

Non-Representational Memory.

The nature of memory is key to understanding the effects of meditation. NGS theory argues that memory is not representational, in that data or programs are not encoded like in a computer, to be “read” and “executed” later for repetition of performance. Rather, memory is a reflection of how an input similar to one associated with past patterns of synaptic connection can trigger a repeat performance, even in a different context and time period.[13] Memory as such is entirely embodied. This model of memory will have powerful implications for the meditation process.

Global Mapping.

Global mapping describes the interaction between the hippocampus, basal ganglia and cerebellum and the cortex during a sensorimotor process, stressing the integrated and continuous nature of associating motor behaviors and sensory input in the course of behavior. The cortex does not execute a command to the motor system based on sensory data. They both continually and reciprocally effect each other in the execution of a behavior.[14] Global mapping relates to memory in that long-term changes in the strength of synaptic patterns due to past behavior tends to favor mutual reentrant activity between those groups (represented in patterns).[15] This plays a role in the automation of behavior, an element that Buddhist practice seeks to reduce, and the stability and maintenance of the Self process.

Concept.

A concept is the brain’s mapping of its own activities or global maps. It allows for an abstraction of global mapping from the immediate context in which it originally arose.[16] If, for instance, a global mapping of the sensorimotor process involved in a cat’s surprise is mapped, the brain will be able to relate this mapping pattern with a value input—perhaps in this case a negative one. Value-category memory results when output from the diffuse modulatory value systems adaptively strengthens or weakens the connectivity of a concept like in the example above.[17] The process helps to explain the connection between meaning and memory, and suggests why traumatic memories (flooded by value systems) are so difficult to lose and prone to repetition. The mind’s propensity toward the classification of the world and behavior in this manner has important implications for Buddhist practice.

Primary Consciousness.

Primary consciousness manifests when the maps of the sensory modalities, reentrantly connected, interact with value-category memory, tying present sensory input to associations and value-laden concepts from past experience.[18] It creates a remembered present. This confers the evolutionary advantage of constantly relating current input to past associations, allowing for avoidance of past dangers and gravitation towards rewarding situations. A certain level of neural complexity is required, which is the balance of differentiated functions and their integration (statistical dependence on each other’s behavior for their own). Differentiation without integration leads to lots of information but not tied into a scene. Integration without differentiation leads to a state where functional specialization is at a low level, thus not providing the variety components necessary to construct a scene.[19]

Dynamic Core.

The dynamic core is the current but constantly changing pattern of reentrant neuronal groups that are active at any one time.[20] The process of their reentry (between structures described broadly above) is the basis of consciousness. Many properties that we would expect from this system are found in our consciousness. We will examine these properties when we look at their connection to the meditational process.

Conscious and Unconscious.

The relationship between the conscious and the unconscious (automated behavior) is a theme running throughout Buddhist practice. NGS theory provides a simple but elegantly convincing explanation for the question of why neural activity that is effecting behavior is not included in the dynamic core. The basic observation is that there are circuits that begin with output from cortical areas but are not heavily reentrantly connected with those areas. Instead, the pathways run in long loops as in the basal ganglia, and are functionally segregated and independent from other areas.[21] These structures then connect back to the cortical areas in select locations, not massively like reentry would necessitate. What

this all means is that when an output is made from the dynamic core to these areas, the areas then carry out the behavior in an isolated fashion from the core, therefore not in the conscious mind. There is feedback, not reentry. Another type of automation may occur in the cortex with the formation of splinter cores. It is well known that individuals can have functions that indicate conscious activity and yet not have this information reach their awareness (as in the case of blind sight, where though people are blind they are able to avoid objects in their path). It is possible that these splinter core remain functionally isolated from the dynamic core, contributing to behavior but not to awareness.[22] The process of deautomation of behavior, both mental and physical, is central to Buddhist practice.

Higher Order Processing.

The latest and most complex process to arise from evolution has been the development of higher order processing, encapsulating symbolic representation in language and the creation of a symbolic world and Self. NGS theory has yet to posit a detailed analysis for the process of language, but applies principle we have already learned of reentry to explain the manifestation of higher order processing. In brief, the development of the language areas (Wernicke's and Broca's areas) and their reentrant connections to the conceptual areas of the brain is the basis for higher order processing.[23] This allowed for the symbolic representation of brain states that has rapidly built on itself into the creation of a Self and a symbolic representation of the world. Luckily, we do not need at this time to have a detailed understanding of language areas to apply the theory to meditation and Buddhist insight. The basic observation of the connection between symbolic representation and brain states is the last piece we require to layout a substantial theory for the neural process of meditation and mystical insight.

Meditation and Neuronal Group Selection Theory

As we approach the task of bridging the gap between neuroscience and Buddhism, we are confronted with a variety of obstacles from the onset. One the primary obstacles is the use of specialized Buddhist language that few but practicing Buddhists understand with any clarity. The use of this terminology also creates a tendency in some minds to exotify the states to which they refer, implying either that they are borderline supernatural, psychopathological in the sense of abnormal, or just very removed from "science." Given that there are already tremendous challenges in integrating the subjective realms of psychology with the empirically-based world of hard sciences, these further linguistic difficulties can prove near fatal to acceptance and mainstreaming of the links between neurology and mysticism.

In the interest of providing as smooth a transitional process as possible, this paper will restrict itself to using contemporary Zen masters who use more mainstreamed psychological terminology along with specialized Buddhist language. Because the Zen schools posit a transmission of Original Mind from Zen master to Zen master[24], we will conclude that the state of experience of the contemporary masters are on par with that of older masters. With this assumption, the difference will only lie in the use of language to describe the same processes, which in our case favors the contemporary. As we will touch upon later, the analysis of Zen Buddhism from this perspective applies well to Buddhism and even other mystic practices across the board. While there is certainly variation, the fundamental processes are similar and can be extrapolated out of the same models of consciousness and meditation.

The Soto Tradition in the Ordinary Mind School of Zen.

The contemporary school to which we will primarily refer is the Ordinary Mind School of Zen. The main force behind the Ordinary Mind School of Zen is Joko Beck, author of *Everyday Zen* and *Nothing Special*, both collections of dharma talks to her students. Beck began practicing Zen in her forties with Maezumi Roshi, Yasutani Roshi and Soen Roshi. In 1983 she was designated Maezumi Roshi's third Dharma Heir, and she moved to the Zen Center of San Diego where she currently lives and teaches.[25] Because she has been designated as part of the lineage drawing back to Bodhidharma, we will consider her an authentic representation of the Soto Zen mind and process.

As Beck describes Soto Zen practice, it is essentially process of continually bringing attention away from thinking and reactions back to the present moment of sensory input. She writes, "When we are experiencing non-verbally, we are walking the razor's edge—we are the present moment...the razor's edge is what Zen practice is." [26] This continual practice gradually allows the meditator to "see through" the apparent reality of the Self and its reactions. As

Shinzen Young phrased it, meditation allows for the de-identification with the seemingly "rock-solid" representations of Self and the world that come out of our use of language and thinking.[27] Beck describes this process in relation to meditation and everyday mindfulness:

The best way to let go is to notice the thoughts as they come up and to acknowledge them. 'Oh, yes, I'm doing that one again,' and without judging, return to the clear experience of the present moment... the value of our practice is the constant return of the mind into the present, over and over and over... Since [thoughts] basically are not real, at some point they get dimmer and less imperative and we find there are periods when they tend to fade out because we see they are not real.[28]

Beck repeatedly refers to the "observing self" that is cultivated through Zen practice. By shifting attention continually to the present moment and de-identifying with thinking, the non-involved, non-judgmental observing self is strengthened. Beck goes on to describe it as, "empty. Instead of separate observer, we should say there is just observing...we learn that not only is the observer empty, but that which is observed is also empty." [29] The process of returning attention to the present moment involves the dissolution of the previous boundaries of self and environment. Beck referred to this distinction as the difference between, "I am experiencing," and "just experiencing." [30] There is certainly no self with a past and future, but, just as importantly, there is no self in the present. There is simply the continuous phenomenon of sensorimotor behavior and awareness.

The most immediate neural analysis that can be offered is to hypothesize that the meditator is somehow achieving a greater and greater return to primary consciousness. The non-reliance on the representational world built synthetically by higher order processing is replaced by "walking on the razor's edge," the present moment of consciousness. While this explanation seems elegantly adequate, and has been offered by Edelman himself on the subject of mysticism [31], it is by far an oversimplification and begs many questions. This "regressionary" argument echoes somewhat similar ones made by Freud and repeated continually with little evidence in many scientific circles. The fact remains that mystics can and do use language and categorization, and can do so without impinging on their enlightenment (in positive samadhi). Mystics also possess a freedom of attention and will that is entirely unlike an animal who is trapped in primary consciousness. These are some of the many problems we face when we try to simplify the process to this extent.

Attention, Automation and Properties of the Dynamic Core.

One of the central processes in Soto Zen is the use of attention to reduce automation of behavior, both mental and physical. There is a natural tendency in the mind to automate behaviors to "conserve attention or consciousness" for new and more complex tasks that can be supplemented to a task that previously required all of attention. This is the basis for higher level learning where "practice makes perfect." Automation also lies at the heart of the development of the Self, whose likes, dislikes and other affectional characteristics are determined largely by conditioning. We can posit that value-category memory and global-mapping are responsible for this phenomenon, as the past activity of global-mapping coupled to a value response (hunger, pain, pleasure, etc) will leave strengthened synaptic connection patterns between the involved neuronal groups, predisposing a similar response which again reinforces the "reality" of the like, dislike or other reaction. Language makes this process far more efficient. Beck describes the conditioning process from the Buddhist perspective:

Once we begin to use language the rapidity of this contracting increases. And particularly as our intelligence increases, the process [of conditioning] becomes really speedy: now we not only try to handle the threat by storing it...we relate each threat to all of the previous ones...and so the process compounds itself.

[32]

Soto Zen practice uses attention to decrease the power or reality of these automatic thinking and reaction patterns.

NGS theory explains the role of attention in deautomation through its neural definition of the terms. Attention is the ability to restrict or broaden the subset of neural groups that are active in the dynamic core. Automatic processing is by definition outside of the dynamic core, and may or may not have the potential of entering it. When an automatic process

is brought into attention, it no longer becomes automatic nor remains as functionally isolated from interacting with other processing areas. This means that its recreation is less based on memory and more on the continual and reciprocal interactions with the cortical sensorimotor maps. Rather than having the sensorimotor maps activated at the end of an automatic loop, they are richly interacting with the memory of the global-mapping as it is recreated. This process explains the increased creativity experienced when attention is focused on an otherwise automatic task (like during musical performance for example), and, in the context of Buddhism, explains the increasingly spontaneous character of meditators through practice.

Meditation and the Creation and Maintenance of the Self.

The normal state of the human mind contains fairly high degrees of automation of mental and physical behaviors and reactions, which through neural selection tend to only further stabilize themselves. NGS theory would support the observation that repeat performances encourage repeat performances rather than innovation unless there are specific competing factors. This is just as true on the level of self-centered cognition. I wish to propose, however, that there is another process at work in the creation and maintenance of a Self, and it is one that Soto Zen practice purposely thwarts.

The language and concept areas of the cortex are massively reentrantly connected. A stable Self arises because the dynamic core so often includes the language and concept areas, to a point where not only are sensorimotor inputs referred to "commentary" but thought itself is recursively-referential. The "reality" of one thought is validated by reference to another, until a coherent process ensues of self-validation through self-reference. "Reference" means that the activity of neuronal groups involved in thinking perpetuate their activity even as the content changes or as new sensorimotor inputs are introduced. The key observation is that the Self is a self-validating, internally coherent process that depends on its continual inclusion in the dynamic core for maintenance. Again, it is important to realize that the Self as described here is not a program that can be captured or stored in the brain. It is a process that requires a certain activity to exist, and in the absence of that activity breaks down (just as in the presence of that activity it grows stronger). (As such, it is more accurate to call it a Self-process rather than the traditional Self-concept) Soto Zen is exactly designed to break down the self-referential process that sustains its sense of reality and coherence.

By continually returning the attention to the present moment, the brain is controlling which neuronal groups are active in the dynamic core. Essentially, it is excluding most areas except for the currently active sensorimotor maps. When the brain begins to automatically react to sensorimotor input with thinking or value-categorizations, the meditator gently returns attention to the sensorimotor maps. By doing this the self-referencing and self-validating process is interrupted, weakening it and allowing the mind to see a thought as just a thought (instead of a "reality"). Concepts of good, bad and neutral which the mind normally tacks onto any object are not allowed to rise into consciousness, being replaced instead with value-neutral sensorimotor input. This is very possibly the mechanism behind the use of attention to reduce attachment and aversion. If the above process is responsible for the path to enlightenment, then it also helps explain why concentrative and awareness practices are both effective, because both interrupt the self-referential process, though in different manners. It would also explain why cultivation of concentration is necessary even in a shikantaza type of sitting.

Meditation practice as described above relies on the capacity limitation attribute of the dynamic core. Edelman describes the capacity limitation as, "the upper limit on how many partially independent sub-processes can be sustained within the core without interfering with its integration and coherence." [33] The human ability to willfully control which areas are active seems to be the foundational element in meditation practices. The above explanation also accounts for gradual and sudden insight. Due to the powerful conditioning and strong predisposition of the human mind for thinking, the de-conditioning process in general is long and very gradual, as the synaptic strength of the reentrant circuits between the language and conceptual areas weaken. This process corresponds to the polishing of the mirror. Sudden insight, however, depends on a critical failure in the Self process. With this insight we understand, as Huang Po phrased it, that there is no mirror to polish. A Self process can be weaker or stronger based on its stability, as in adolescence versus adulthood (for some anyway). We can also posit that at some point in early development, a "critical mass", so to speak, is reached in the complexity and coherence of self-referencing and self-validation where the Self takes on a tangible reality. We can perhaps also posit a point of critical failure, where even the residual illusion of reality left from conditioning breaks down as the entire process is weakened. Years of gradual practice would help lay the foundation for this failure. This failure may be accompanied by or related to a release of neurotransmitters from the value-system (possibly serotonin), as evidenced by the euphoria and somewhat permanent effects on neural activity. This is further supported by the enlightenment-like experience that drugs like LSD can induce, which effects the serotonergic system. [34] Interestingly, serotonin is also one of the primary neurotransmitters implicated

in the regulation of wakefulness and the controlling of aggression.[35]

Impermanence and Buddha-nature.

We are now in the position to return to questions we posed at the beginning of the paper: What is the nature of the experience of impermanence and the knowledge that all sentient beings possess Buddha-nature? As suggested earlier, impermanence as experienced by a meditator is the absence of use of concepts that lend a sense of permanence to the process of consciousness. As meditators return their attention to the current sensorimotor inputs, they are experiencing the process of consciousness, which by the nature of the dynamic core is continuous and changing.[36] Their knowledge of impermanence is therefore embodied in the process of consciousness itself.

The insight that all sentient beings possess the Buddha-nature is based on perceiving that the Self process is a synthetic creation depending on its own inner coherence for a sense of "reality." Perception of the false nature of the Self process reveals the substratum of consciousness that is present regardless, in those who possess higher order thinking and those who only possess primary consciousness. However, because Buddha-nature is the absence of the Self-process, ALL things possess the Buddha-nature, including rocks, grass, sound and a non-enlightened person.

The Necessity of Thinking.

Beck and most meditators have observed the difficulty in getting the mind to stop thinking, even after years and years of practicing. Beck stresses that the object is not to rid mind of thought (because, after all, thought is necessary to function), but a change in the way thought is "held" or identified with. She also makes the distinction between technical thinking, like that involved in baking a cake or doing physics, and self-centered thinking. She contends that the latter is what creates suffering. Through practice the self-centered thinking quiets down, and the meditator is simultaneously able to see it as empty and not-as-self. The question remains, however, why the meditator cannot actually stop thinking (although, through concentration, they can block it out). NGS offers a simple explanation, drawing the parallel to other cortical areas. The language areas are part of the dynamic core under most circumstances, and as such are by definition active. They are not a box or a "program" as some computer-based models might posit, where they could be turned off or not run. Just as one cannot "turn off" seeing or hearing, language and thinking is a basic component of the human dynamic core except under the conditions of concentration that would exclude it. It is worth noting that through evolution we have probably developed just the opposite, a powerful predisposition for these language centers to be very reentrantly active, or language itself would not have evolved.

The ability to exclude neuronal groups from the dynamic core leads to the interesting question of what would happen if more and more were to be excluded? Would a "dropping off of mind and body" occur? Or perhaps this is the root of absolute samadhi? Until a better understanding is reached on the exact constraints of the capacity limitation of the core and the process of narrowing or broadening attention, these questions will likely remain open ones.

Conclusion.

Another conclusion of this study is one that Buddhists have been making for hundreds of years: that Buddhist meditation is first and foremost a study of the human mind—the normal functioning of the human mind, but it entails an embodied understanding that changes the process of the Self. Therefore we should not view the study of meditation as an examination of some "special" mind state, an "altered state of consciousness." Meditation and Buddhist insight concerns the normal function (or dysfunction) of the human mind.

The ability to control the active neuronal groups in consciousness exists along side the natural tendency to automate behavior. We have, however, traded the evolutionary advantage inherent in the rapid automation of behavior for a state where we are prisoners of representation. The simple fact is that the evolutionarily determined function of our minds is the basis for its particular operation, not our happiness or the veracity with which it represents reality. In fact, by its nature and function the mind has evolved to 1) demarcate the "boundaries" between a Self (which encompasses the stable mental and physical entities on which individual function depends) and the environment, and 2) label the

environment according to our value criteria in relation to this Self. In other words, the human mind is designed to be self-centered in the sense of individual survival. This self-centeredness must necessitate suffering, however, as want and pain are two of the central tools of homeostasis. This, combined with the impermanent nature of consciousness, is the evolutionary origin of Buddha's first of the Four Noble Truths, that life is suffering. Ironically, after taking hundreds of thousands of years to be constructed, the human brain and its desire for release has developed a system that deconstructs itself, a self originally built from desire and self-reference.

Unfortunately, mystical practice has been restricted to the select who take the paths of the meditator. We can expect, however, that with the steady advancement of brain science, the evolutionary origins of our value orientations will become more and more glaring, along with the degree of their contemporary irrelevance and opposition to many culturally held values. As we realize the extent that we have been handed ourselves, we will, perhaps, come see our Self more objectively, as a mystic might, and rather than blindly acting out our evolutionary drives towards self-perpetuation, dominance, etc, we may consider methods of neurally altering the value criteria in the brain and then through our genes. There is an inevitable convergence between the findings of brain science and the findings of mystics, and as they converge, we can expect and hope that humans will collectively experience a major crisis in identity such that, in collective as well as individual behavior, we are finally able to "let go".

A Critical Postscript. [Adapted from Edelman]

More and more researchers today are attempting to link subjects from "hard sciences" to mystical practices, particularly in the areas of neuroscience and physics. Despite the increased attention, many of these efforts will fall short, either due to their faulty assumptions or due to their lack of an adequate process-based theory of consciousness.

The attempt to link findings in physics and quantum physics to mysticism parallels the attempt to do the same to mind in general. This approach, however, is doomed to failure due to the degree to which these theorists ignore the biological basis of the consciousness process and mystical practice. The attempt to hypothesize the manifestation of consciousness (and therefore linking it to mysticism) is predicated on the notion that it arises as a kind of emergent property of matter. Some have argued that the relationship between consciousness and quantum physics is observed in Heisenberg's Uncertainty Principle, and that the resolution to the question of consciousness will come with the resolution of the questions of quantum physics.[37] While these books contain many descriptions of physics, they largely ignore psychology and biology and fail to do more than ask interesting questions.[38] The reasons are simple: the answer to consciousness and thus to mysticism will be found in the brain and its structure and process because that is where consciousness functionally and developmentally arose.

For those theorists who have chosen to examine the brain and process of mysticism, a common approach is taken, as much from a previous lack of adequate theory as from a limitation in understanding. Scientists like James Austin have attempted to integrate much today's neuroscience with Zen practice in the tome *Zen and the Brain*. The bulk of *Zen and the Brain* is a fairly isolated but extensive treatment of neuroscience or its relationship to psychology. Austin presents theories others have posited about the mechanism behind meditation and enlightenment, many of them relying on simplistic models of neurotransmitter release. He doesn't comment on them in depth and fails to offer a substantial alternative vision of his own. At places Austin attempts to locate the areas and structures of the brain where the processes of mysticism take place, but because he lacks an adequate theory of the process, he is limited to positing that this or that structure or pathway is involved, usually because its activity is necessary during the particular cognitive state. It is, however, a large leap from saying that this structure is involved, to saying that it is the cause. Austin seems to recognize this and so usually stops at suggesting an area's involvement. While somewhat useful, a holistic description of the process is the crux of the matter if we are to understand the neural basis of both consciousness and mysticism.

It is worth noting that a comparable approach has been taken by most neuroscientists, who, hesitant to propose a process of consciousness, satisfy themselves with pointing out structures in the brain that when lesioned or stimulated effect or even negate consciousness in the subjects. Short of an adequate description of process, scientists are forced to make statements positing that certain cognitive functions get processed here or there involving certain neurotransmitters, which of course largely begs the question. As in the study of consciousness, scientists must begin to rely on process-based models to explain mysticism if they are to move beyond the current impasse of understanding.

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