Neurobiology of Chakras and Prayer

with Richard W. Maxwell, "The Physiological Foundation of Yoga Chakra Expression"; and Ruth Stanley, "Types of Prayer, Heart Rate Variability, and Innate Healing"

THE PHYSIOLOGICAL FOUNDATION OF YOGA CHAKRA EXPRESSION

by Richard W. Maxwell

Abstract. Chakras are a basic concept of yoga but typically are ignored by scientific research on yoga, probably because descriptions of chakras can appear like a fanciful mythology. Chakras are commonly considered to be centers of concentrated metaphysical energy. Although clear physiological effects exist for yoga practices, no explanation of how chakras influence physiological function has been broadly accepted either in the scientific community or among yoga scholars. This problem is exacerbated by the fact that yoga is based on subjective experience, and practitioners often shun objective descriptions. This essay builds on earlier work hypothesizing that intercellular gap junction connections provide a physiological mechanism underlying subtle energy systems described in yoga as well as other disciplines such as acupuncture. Three physical aspects of chakras are distinguished that are integrated through gap junction mechanisms and are proposed to have arisen during embryological development. Furthermore, electrical conductance associated with a high concentration of gap junctions could generate phenomena that, when subjectively experienced, have the radiant qualities attributed to chakras. This theory provides a scientific rationale for previously unexplained details of chakra theory and offers a new orientation to conceptualizing and studying such subjective phenomena.

Keywords: acupuncture; cakra; chakra; electrical synapse; gap junction; glial syncytium; kundalini; meditation; nervous system development; subtle energy; yoga

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One of the challenges in the scientific study and interpretation of yoga practices is that yoga uses concepts different from those of Western science to explain its benefits. Recent discussions about the integration of yoga into Western health practices emphasize the need for testable hypotheses and models for how yoga works (Goldin and Manber 2006; Shapiro 2006; Sherman 2006). Yoga includes a spiritual anatomy of nonphysical control centers, called chakras (also spelled cakras). By attaining mastery over each chakra and its influence over particular glandular secretions, all aspects of mental function are said to become controlled (Sarkar 1994). For any research to accomplish a comprehensive explanation of yoga, it must explain the nature and role of chakras.

There is extensive research demonstrating physiological effects of various yoga practices. Yoga practices can modify many physiological systems, including respiratory (Bhargava, Gogate, and Mascarenhas 1988; Telles, Nagarathna, and Nagendra 1994; Spicuzza et al. 2000; Brown and Gerbarg 2005), cardiovascular (Bernardi et al. 2001; Raub 2002; Bharshankar et al. 2003; Harinath et al. 2004; Sarang and Telles 2006), autonomic (Wenger and Bagchi 1961; Bujatti and Riederer 1976; Vempati and Telles 2002) and central nervous systems (Elson, Hauri and Cunis 1977; Corby et al. 1978; Lazar et al. 2000; Arambula et al. 2001; Aftanas and Golosheykin 2005). Yet this research largely excludes any reference to chakras. If chakras exist and can influence physiological activity, some aspect must be accessible to objective analysis. The discovery of a physical system that correlates with purported chakra functions would greatly enhance the study of yoga practices. This essay elaborates a theory originally presented by Charles Shang (2001) that proposes that chakras are associated with embryological organizing centers in the central nervous system (CNS). In an examination of the implications of this theory, many critical areas of confusion concerning chakras are explained. First, characteristics commonly attributed to chakras are elaborated.

Basic Chakra Concepts

Georg Feuerstein specifies in his yoga encyclopedia that yoga formulations typically describe seven chakras, although additional chakras are described in some systems. He defines chakras as "psychoenergetic vortices forming the major 'organs' of the body composed of life energy (prana)" (Feuerstein 1997, 68). In a classic commentary and translation of the Sat-Chakra-Nirupana, chakras are described variously as "vortices of etheric matter" and "centres of consciousness" (Avalon [1919] 1974, 7, 159). C. W. Leadbeater describes chakras as "saucer-like depressions or vortices" that are "points of connection" between the physical body and an invisible part of the body he calls the "etheric double" (Leadbeater [1927] 1994, 2–3). Energy flows through these points of connection, and the magnitude of the energy flow can vary greatly. "When quite underdeveloped they appear as small circles about two inches in diameter, glowing dully in the ordinary man; but when awakened and vivified they are seen as blazing, coruscating whirlpools, much increased in size, and resembling miniature suns" ([1927] 1994, 4).

While chakras are not considered to be physical, they frequently are associated with particular anatomical locations and are considered to have direct influence over specific, select aspects of physical and mental functioning. Table 1 (see next page) specifies locations associated with chakras by various authors. Shyam Sundar Goswami lists a set of "surface points" along the ventral body surface and "physical positions" ([1980] 1999, 293) within the CNS for chakras, despite his emphasis that chakras are nonphysical. Shrii Shrii Ánandamúrti's (also known as Prabhat Rainjain Sarkar) locations are described as "concentration points" (1996, 76), not the true locations of the chakras which are considered to be within the CNS. Thus, there is a distinction between locations at which mental focus may stimulate chakras and the actual site of the chakras. Although Feuerstein questions how closely the link between physical locations and chakras can be made, he concludes that chakras are generally accepted to have positions within the CNS (Feuerstein 1997). Confusion between the CNS location, concentration points and other locations of chakra influence often occurs. One example of this confusion is demonstrated by Dharma Singh Khalsa and Cameron Stauth when they specify locations that are sometimes more dorsal ("behind the heart") but also specify "center of forehead" (Khalsa and Stauth 2002, 168), which is a superficial and ventral location. Dennis Chernin gives a mix of "associations" (2002, 88–89) with the CNS and autonomic nervous system (ANS) and implies that chakras influence physical function through those associations. A mechanism is not specified, and chakras are loosely described as a "force field" (Chernin 2002, 77). With Harish Johari, it is unclear how his use of the term *plexus*, as in "cerebral plexus" (2000, 147), relates to the brain regions he designates. Another confusing example is when Khalsa and Stauth state, "Each chakra is located in the exact same area as a major nerve plexus, and an important endocrine gland," while also stating that chakras "are vertically aligned along the spine and head" (2002, 163). Table 1 shows three aspects of chakras (components in the CNS, components in the ANS, and components in the endocrine system) that are variously intermingled by these authors. When abstract concepts such as "vortices of etheric matter" are also included, the potential for a scientific analysis appears hopeless.

The challenge for anyone interested in explaining chakras is to be able to demonstrate how something nonphysical could interact with the physical. The magnitude of the challenge is framed by Goswami, who presents a comprehensive critique of attempts to associate chakras with physical structures ([1980] 1999, 14–20). His chief complaint is associated with overly zealous attempts to reduce chakras to a physical structure. However,

TABLE 1

Associations between Chakras and Anatomical Sites

Chakras	A	B	C	D	E	F
1. Múládhára	Above the perineum	At the anus	Perineal point (Coccyx, segment II)	Perineum, base of spine	Sacral and pelvic nerves, coccygeal plexus	Base of spine
2. Svádhist'hána	Region of the genital organ	At the genitals	Genital point at root of penis (Sacral 4)	Genital region	Hypogastric plexus, lumbar-sacral plexus	Behind lower abdomen
3. Manipura	Region of the navel	At the navel	Navel point (Lumbar 4)	Part of vertebral column associated with the navel	Celiac plexus	Behind the navel
4. Anáhata	Region of the heart	At the heart	Thoracic point (Thoracic 9 or 10)	Heart region of the vertebral column	Cardiac plexus	Behind the heart
5. Vishuddha	Region of the vocal cords	At the throat	Cervical point (Cervical 4)	Cervical part of the spinal column	Pharyngeal plexus	Throat
6. Ájiṇá	Between the eyebrows	At the center of the head, between and behind the eyebrows	Eyebrow point (Caudal 3rd ventricle)	Medulla plexus, pineal plexus	Midbrain	Center of forehead, or third-eye point
7. Sahasrára	Crown of the head	At or above the crown of the head	Head point (Extra-cranial)	Top of the cranium, cerebral plexus	Cerebral cortex	Top of head

Delineation of physical locations associated with particular chakras by various authors: A. Ánandamúrti (1996), B. Feuerstein (1997), C. Goswami (1999), D. Johari (2000), E. Chernin (2002), F. Khalsa and C. Stauth (2002). There is a general consistency in the anatomical region of the chakra. However, the locations demonstrate a confusing mix of CNS and peripheral sites, some precise but others quite vague and sometimes inconsistent with normal physiological terminology.

if chakras were truly independent of physical structures, why would there be any correspondence with physical locations? This dilemma can be resolved only if there are physical systems at least closely related to chakras through which the physical effects of chakras are manifest. A possible solution lies in a subtle physical system whose importance has become increasingly recognized within the past few years.

Gap Junctions

Acupuncture is a clinical discipline with demonstrated scientific validity that presumes to manipulate subtle energies unassociated with any known physiological system (Kaptchuk 2002). Some efforts to resolve this dilemma have focused on mechanical signaling (Langevin, Churchill, and Cipolla 2001). Others have demonstrated that electrical properties are involved (Chen 1996). One model has attempted to unify structural and electrical characteristics and also has proposed that a similar mechanism could explain the existence and characteristics of chakras (Shang 2001). Shang's mechanism is based on developmental control processes that include intercellular coordination through gap junctions.

Gap junctions are hydrophilic passages between the cytoplasm of two adjacent cells created by a hexagonal array of connexin proteins, and probably a newly discovered family of pannexin proteins (Söhl, Maxeiner, and Willecke 2005) (see Figure 1). Approximately twenty different connexin related genes have been identified on the human and mouse genomes (Evans and Martin 2002). Gap junctions composed of different connexins have different conductance and gating properties associated with exchange of

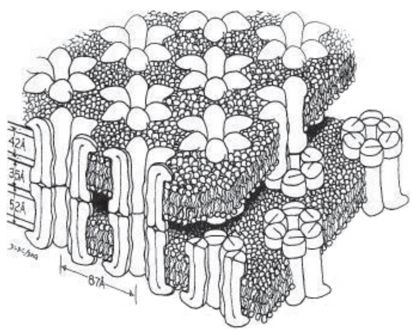

Fig. 1. Gap junctions channels across two cell membranes. This image depicts an X-ray diffraction analysis of a section of two juxtaposed cell membranes with gap junctions penetrating through the two lipid layers. Gap junctions are formed by two hexagonal arrays of connexin proteins (large white clusters) that link across the membranes of adjacent cells forming hydrophilic passages. The passages are no greater than about 20 Å wide. Reprinted with permission from Makowski et al. 1977.

small molecules and ions capable of creating electrical conductance (Bukauskas and Verselis 2004). Gap junctions play an important role in synchronizing endocrine secretion (Berthoud et al. 2000; Røttingen and Iversen 2000; Funabashi et al. 2001; Meda 2003), in the function of the heart (Verheule et al. 1997; Dhein 1998), in the synchronized firing of neurons (Colwell 2000; Bou-Flores and Berger 2001; Solomon, Chon, and Rodriguez 2003; Hewitt et al. 2004), in interactions between neurons and glial cells (Cotrina and Nedegaard 2000; Kirchhoff, Dringen, and Giaume 2001), and in coordinating activity in many embryological processes.

Gap junctions have an essential role in embryological processes. The density of gap junctions is greatest during embryological development (Fulton 1995; Leung, Unsicker, and Reuss 2002), and many developmental processes are affected by gap junctions, including left-right patterning (Levin and Mercola 1998), the development of limb buds (Makarenkova et al. 1997; Law et al. 2002), the migration and survival of neural crest cells (Huang et al. 1998; Bannerman et al. 2000; Cai et al. 2004), heart development (Ewart et al. 1997), the development of the nervous system (Dermietzel et al. 1989; Menichella et al. 2003; Montoro and Yuste 2004; Tang et al. 2006), and the control of tumor growth (Naus 2002). Although embryological development in the nervous system is highly regulated by growth factors, gap junctions play an important role through creating boundaries (Dahl, Willecke, and Balling 1997), modulating cell migration (Xu et al. 2001), modulating cell proliferation (Bittman et al. 1997), and mediating the transmission of cell signaling molecules (Lo 1996).

The synaptic communication occurring between neurons through the release of chemical neurotransmitters such as serotonin, dopamine, and norepinephrine is well known (Cooper, Bloom, and Roth 1996). Synapses using ions (called electrical synapses) are also present between neurons and are created by gap junctions (see Figure 2) but constitute only a minority of the synapses present (Bennett 1997; Hormuzdi et al. 2004). In contrast, gap junctions between glial cells are extensive and have been shown to be important in a number of mature CNS systems. Brain astrocytes, a type of glial cell, form an extended network (syncytium) through gap junctions in which neurons are embedded, facilitating interdependence between the functions of astrocytes and neurons (Kirchhoff, Dringen, and Giaume 2001). Demyelination and axonal atrophy in Charcot-Marie-Tooth Disease is associated with genetic mutations of a particular gap junction protein associated with myelin in Schwann cells and oligodendrocytes (Ionasescu 1998; Menichella et al. 2003). A pan-glial gap junction network has been proposed that links astrocytes and oligodendrocytes (Fróes and Menezes 2002). Glial gap junction communication has effects on brain reinforcement systems through an association with dopamine (Bennett et al. 1999). Gap junctions influence synchronous neuronal firing that may be associated with seizure activity (Ross et al. 2000). Gap junction activity modulates inspiratory motorneuron synchronization and respiratory rhythm (Dean et al. 2002; Solomon, Chon and Rodriguez 2003). Gap junctions are necessary for rhythmic coupling of cells within the suprachiasmatic nucleus (SCN) (Colwell 2000). Blocking gap junctions disrupts the circadian rhythm of cell firing in the SCN (Prosser et al. 1994; Long et al. 2004). Activity of the SCN generates circadian rhythms affecting the whole animal through multiple mechanisms including the control of pineal secretion of melatonin (Larsen, Enquist, and Card 1998; Perreau-Lenz et al. 2004).

Early in brain development electrical coupling of neurons through gap junctions is widespread, precedes chemical synaptic activity, and has been proposed to contribute to neuronal circuit maturation (Fróes and Menezes 2002; Hormuzdi et al. 2004; Sutor and Hagerty 2005). In the neonatal spinal cord of the rat, stable motor activity can be produced without action potentials as a result of synchronization through gap junctions (Tresch and Kiehn 2000). Such synchronization has been proposed to be critical for the establishment of proper chemical synapse connectivity (Saint-Amant and Drapeau 2001). Thus, at an early point in development, electrical circuits predominate in the CNS, but as the cortex develops, chemical synapses gain predominance (Kandler and Thiels 2005).

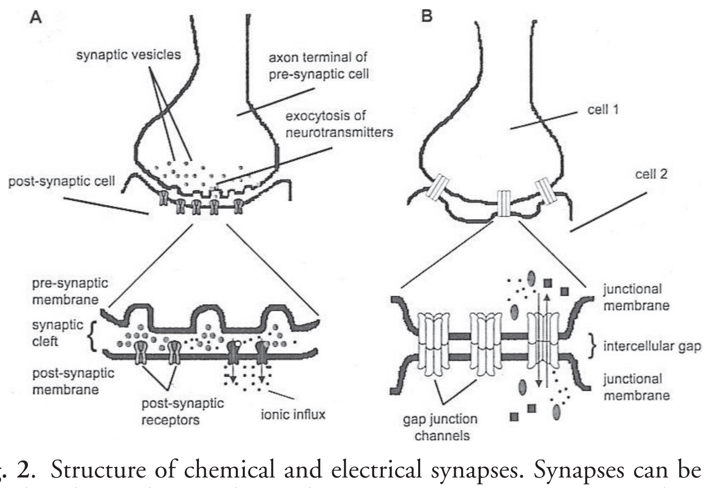

Fig. 2. Structure of chemical and electrical synapses. Synapses can be either chemical or electrical. A. In chemical synapses, neurotransmitters are released into the synaptic cleft between two neurons, resulting in gating of ion channels, generating in this example an ionic influx across the post-synaptic membrane. In a chemical synapse the effect is unidirectional. B. Electrical synapses are formed by gap junctions that create pores between two neurons allowing an exchange of larger molecules, including ions (small circles), metabolites (squares) and small second messenger molecules (ovals). Electrical synapses allow a bidirectional exchange between neurons. Drawing reprinted with permission from Hormuzdi et al. 2004.

The Dorsal Neural Tube and Neural Crest Cells

Shang proposed that acupuncture points arise from a higher density of gap junctions between cells that are remnants of organizing centers that controlled morphogenesis in that region (2001). This has powerful implications concerning CNS development and a physical system potentially associated with chakras. In the developing embryo, nervous tissue first develops as a flat sheet of cells called the neural plate (see Figure 3). At an early point, the side edges of the neural plate begin to fold toward each other, ultimately forming a tube that develops into the brain and spinal cord (Gammill and Bronner-Fraser 2003). Although chemical signals promote these movements, gap junctions have been shown to have a role in neural tube closure (Ewart et al. 1997). An abnormal expression of one type of gap junction is one of the causes for failure of the neural tube to close. The presence of increased levels of gap junctions in the neural folds is supported by the observation that a portion of the neural folds generates an electrical current (Hotary and Robinson 1994; Shi and Borgens 1995). If there is a high density of gap junctions at the edges of the neural folds, the points at which the two edges join should have an especially high density of gap junctions.

The region where the edges of the neural plate join has major developmental importance. In the vicinity of the joined edges, a special set of cells, called neural crest cells, are generated. Neural crest cells become many diverse types of cells, including sensory neurons of the dorsal root ganglia, adrenal chromaffin cells (adrenaline-producing cells), and all of the cells of the auto-

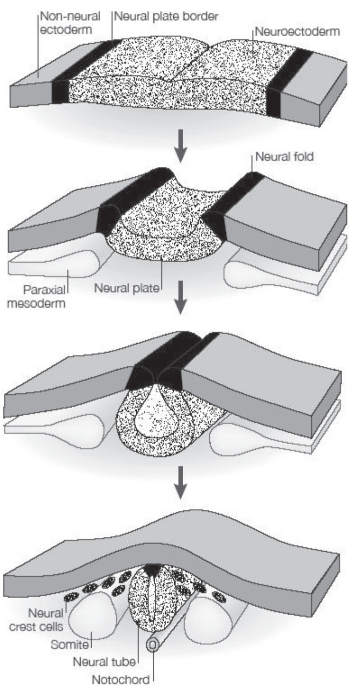

Fig 3. Formation of the neural tube and neural crest cells. The progression from neural plate to neural tube is depicted across four stages. Cells destined to become the CNS are segregated from other ectodermal cells into a plate. Folds emerge at the edges of this plate and extend toward each other. When the folds join, the neural tube is formed. Neural crest cells (mottled ovals) are generated and migrate from the region of the dorsal neural tube where the folds join (black). Drawing reprinted with permission from Gammill and Bronner-Fraser 2003. Modifications were made to the coloring to adapt to a black-and-white format.

nomic nervous system including the neurons and glia of the enteric nervous system (Le Douarin and Kalcheim 1999). Neural crest cells also form bones and cartilage in the face and parts of the head (Helms and Schneider 2003; Santagati and Rijli 2003; Noden and Schneider 2006). Neural crest cells migrate from the dorsal neural tube region in organized sheets or streams (Bronner-Fraser 1994; Kulesa, Ellies, and Trainor 2004). Gap junctions have been shown to be necessary for neural crest cell survival during migration (Huang et al. 1998; Bannerman et al. 2000).

Spinal Centers and Concentration Points

Shang proposed that acupuncture points, and the meridians that link them, arise from underdifferentiated cells that retain high concentrations of gap junction connections (2001). Extending this, he described chakras as remnants of embryological organizing centers within the CNS, possessing a similar high concentration of gap junction connections. It is additionally proposed that direct or indirect connections are maintained between the mature cells arising from neural crest cells and the locations from which they originated. Thus, there would be gap junction links between autonomic cells (and other neural crest derivatives) and centers in the CNS that had a role in controlling their original differentiation.

Chakra locations have sometimes been associated with autonomic plexuses (see Table 1, E), but the relationship between chakras and autonomic plexuses has never been clearly defined. The locations specified for concentration points are often vague, sometimes being specified only as regions (see Table 1, A, D, and F). In the current formulation, concentration points associated with chakras represent locations primarily within the ANS whose activity can be changed by willful concentration. The change in activity produced would have the potential to modify activity in specific centers within the CNS. Those CNS centers represent the physical base of the chakras, the physical structure most immediately connected to subjectively perceived chakra activity. Concentration points for the two highest chakras are at locations (between the eyebrows and at the crown of the head) where there are no major autonomic plexuses. However, bones and cartilage of the face and portions of the head are formed from neural crest cells (Santagati and Rijli 2003) that could retain subtle links to the CNS. Although it is easier to imagine gap junction links between autonomic cells and CNS cells than between bone cells and CNS cells, the peculiar bone-generating function of neural crest cells does provide consistency for this theory. Other cell types also could participate in creating the necessary links.

It is postulated that CNS chakra centers have the capacity to modify broader CNS activity, particularly affecting secretory activity in related endocrine systems. Endocrine function is important in yoga theoretical frameworks because a critical feature of chakras is the control of key mental propensities (vrtiis) modulated by glandular secretions (Ánandamúrti 1988). This is too large a topic to be examined in the current essay, but it is consistent with the somatic-marker theory, the idea that body states can have significant influence over brain states affecting thought and feeling (Damasio, Everitt, and Bishop 1996). This chakra hypothesis differs from other theories recently proposed to explain profound spiritual experiences (Austin 1998; d'Aquili and Newberg 2000; Dietrich 2003; Davidson et al. 2003; Newberg and Iversen 2003) by deemphasizing the role of networks of chemical synapses in favor of electrical networks and endocrine effects.

The effects of focusing on chakra concentration points by yoga novices most likely begin through chemical synaptic systems, modifying activity within various organs affected by shifts in autonomic control consistent with the classic relaxation response (Benson 1976). Subjective sensations experienced when focusing on a concentration point are presumed to arise from a shift of activity in neural pathways. However, this need not occur solely through chemical synapses. It is proposed that the effect of advanced meditation is accomplished by restoring greater strength to the more primitive electrical circuits, particularly at locations capable of exerting broader control, that is, those which are proposed to be the physical bases of chakras. There is increasing evidence that chemical synapses are only part of the neural control process and that under many circumstances electrical synapses (that is, gap junctions) generate important functions, particularly through coordinating the activity of groups of cells (Colwell 2000; Bou-Flores and Berger 2001; Solomon, Chon, and Rodriguez 2003; Hewitt et al. 2004). As a yoga practitioner becomes more adept, subtler systems using gap junctions could be activated, changing energetic states in groups of cells, including opening connections between different compartments within the glial syncytium. Yogic practices could also stimulate increases in the number of gap junction connections. Current evidence demonstrates that connexin expression is a dynamic process that spatially and temporally regulates gap junction coupling between neurons in different brain areas and presumably elsewhere (Hormuzdi et al. 2004).

It is difficult to imagine how subtle gap junction mechanisms could be studied in humans, but a recent Chinese study demonstrates an increase in the expression of a particular gap junction protein (connexin 43) at an acupuncture point in rats using acupuncture stimulation (Huang, Zheng, and Zhang 2005). Acupuncture in humans has been demonstrated to modify limbic and subcortical brain activity in a functional magnetic resonance imaging study (Hui et al. 2000). Glial functions in the brain have been related to many neurological and psychiatric disorders (Hertz et al. 2004). This implies that yoga practices such as chakra concentration exercises and mantra meditation could do more than the current concept of modulating frontal cortex attention circuits (Cahn and Polich 2006), potentially also promoting fundamental changes in neural structures that allow a broader neural/glial syncytium to be established.

This difference between chemical and electrical communication within the CNS and ANS could explain why chakras are perceived to be non-physical. Chemical synaptic activity of the CNS and ANS may be able to be subjectively distinguished from the activity and influence of the chakras because the effect of chemically based nerve function spreads in a manner that is distinct from electrical gap junction networks. The physical base of a chakra is therefore a hub in typically dormant or subordinate electrical circuitry that becomes accessible to conscious control, providing the potential for subtle influence over the activities of the CNS, ANS, and endocrine system. Yoga training and probably other practices provide access to these subtle electrical circuits and functions.

Additional Implications

One demonstration of the value of a theory is its explanatory power. Until the gap junction theory of chakras, little could be said scientifically to justify the existence in classic yoga constructs (Avalon [1919] 1974; Ánandamúrti 1993) of an important dormant energy (kundalini, or kun'd'alinii in Roman Sanskrit) considered to reside at the base of the spine. With this theory, the presence of a chakra and an energy in some relation to the coccyx (and filum terminale, the terminal filament of the spinal cord) can be understood. According to Shang's theory, an unusually high concentration of gap junction linked cells would be expected at the end point of a developmental growth process like the spinal column that ends at the coccyx and filum terminale. It is proposed that the kundalini is, in part, a subjective representation of state changes among polar molecules within a channel in the CNS rising from the filum terminale to the brain. Arthur Avalon recognized the importance of the filum terminale to yoga constructs and noted ([1919] 1974, 105) that while fibrous, the filum terminale also contains nerve cell bodies. In this framework, that channel (sushumna, or sus'umna' in Roman Sanskrit) is a column of gap junction linked cells whose gap junctions open as the kundalini rises. The broader aspects of the sushumna are a product of the glial syncytium extending through the whole volume of the spine and brain. Meditation functions to increase the prevalence of gap junctions and integrate compartments within the glial network, ultimately allowing a full electrical unification of the spine and brain. The subtlest component of the sushumna (brahma-nadi) (Feuerstein 1997, 63) is expressed through a column of cells remaining in the region where the edges of the neural plate joined to form the neural tube. Gap junctions between neurons in the CNS are particularly associated with inhibitory interneurons and contribute to oscillating brain electrical activity (Hormuzdi et al 2004). A column of activated inhibitory interneurons through the spinal cord and into the brain could have a powerful effect in changing states in the CNS. This provides a cellular mechanism for how meditation may shift power in the EEG.

The physical location of the chakras also can be viewed from a developmental perspective. The lower five chakras are associated with sites of developmental control over the five classically defined regions of the spine: cervical, thoracic, lumbar, sacral, and coccygeal. The upper two chakras are located within the brain at points where brain regions have differentiated. During development, the brain first differentiates into three regions: forebrain, midbrain, and hindbrain (Rubenstein et al. 1998). One yoga authority has associated ájiṇá chakra with the midbrain (Saraswati [1969] 2008, 532). This makes sense because that chakra is associated with the most subtle I-feeling (Ánandamúrti 1968), and portions of the midbrain have been described by neuroscientists as the location of the most primitive forms of self-awareness (Panksepp 1998; Damasio 1999). From an embryological point of view, the most likely site of ájiṇá chakra is the highly studied isthmus organizer that controls the differentiation of midbrain from hindbrain structures (Alexandre and Wassef 2003). Following this progression, mechanisms not yet identified that control the differentiation of midbrain from forebrain structures would produce the physical base of the sahasrára chakra. This location is expected to be in the dorsal thalamus, particularly the epithalamus, supporting association of the pineal gland (which is part of the epithalamus) with the sahasrára chakra.

Conclusion

Subjective experiences commonly described by yoga practitioners are reproducible experiences that can be achieved by anyone performing certain introspective practices. Past attempts at identifying a physical corollary to the subjectively experienced chakras have been unsatisfactory because knowledge had not yet existed about a physiological system that was sufficiently subtle. By expanding the gap junction theory of chakras and including additional information about developmental processes within the dorsal neural tube, mechanisms have been proposed to explain disparate elements of chakra theory. Physical systems related to a chakra have three main aspects: a physical base that exists in the dorsal CNS, a concentration point that is activating to that physical base, and influence of that physical base over the activity of particular glandular secretions that have the potential to bias mental function. With appropriate forms of concentration, gap junction linkages in autonomic plexuses and elsewhere, typically subordinated to chemical synaptic activity, may become activated (or regenerated) and result in stimulation of important sites in the dorsal CNS. Additionally, control over glandular functions may be susceptible to modulation by gap junction mechanisms, presumably through autonomic nerves associated with these dorsal CNS sites. Identification of gap junctions within the nervous system has had difficulties, and it is not likely to be easy to find the proposed chakra centers within the CNS in animals or humans. Functional magnetic resonance imaging (fMRI), or perhaps new technologies such as functional near-infra-red spectrometry (fNIRS), together with more refined electrophysiology could potentially yield signs of this underlying physiology. If gap junctions are associated with chakra function, some type of electrical signature should be present that could be identified. At least one researcher has claimed to have identified electrophysiological signs of chakra activity (Motoyama 1981). However, there is no evidence that this work has been subjected to any peer review process.

The potential presence of a physical substrate underlying chakras brings back Goswami's caution ([1980] 1999, 14–20). Could the phenomena associated with chakras be reduced to a solely physical process? The intent of this essay has been to provide a necessary mechanism to explain effects on physical systems that are claimed by yoga practitioners. Other more complex issues associated with subtle states of consciousness potentially independent of physical function have not been addressed. It has been assumed that there is valid truth in the experience of yogis that can provide important information concerning complex aspects of our human condition. Gap junctions are a physical structure, but their functions and mechanisms of control are just beginning to be understood. It is conceivable that subtle properties involved in controlling a medium filled with flowing polar molecules could generate phenomena that, when subjectively experienced, have the radiant qualities attributed to chakras. This offers a potentially dramatic new approach to conceptualizing and examining a special group of subjective phenomena. In order to produce the effects generally claimed, chakras must have physical linkage in addition to purported metaphysical characteristics. To ignore the physical aspects would be just as foolish as ignoring the metaphysical aspects.

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