

*Photograph by Jeff Hazen.*

---

### **Abstract**

The pineal gland is a small gland that lies at the base of the middle brain. Until recently, medical specialists believed it to be an artifact of evolution that had no current valuable use in humans. It has been discovered that not only is the pineal gland responsible for regulating the daily biological rhythms in the body, but it also releases the only endogenous psychedelic substance created in humans. Dimethyltryptamine (DMT) is a unique molecule produced by the pineal gland: its actions may provide a biological framework for the martial arts practices of Sinmoo Hapkido, as well as other martial and spiritual practices.

# The Pineal Gland's Biochemical Function in the Fighting and Meditative Arts Exemplified in Korean Sinmoo Hapkido

by Sean Bradley, N.D., L.Ac.



The pineal gland has long been an object of interest in the medical, spiritual, and martial arts communities. Descartes called it the “seat of the soul” in the 1700s, and many spiritual traditions view it as the anatomical landmark for the “third eye.” Eastern and Western cultures have referred to the pineal gland and surrounding area as the middle brain, sixth chakra, upper *dantian* (Mandarin; Korean *danjun* or *tanjon*), and mind’s eye. They place dramatic importance on this area as a place of focus, concentration, *ki* (life energy) development, and potential enlightenment.

Currently there is very limited research on the pineal gland and its functions in the body; however, in recent years it has been brought more into the spotlight, as it is the source of most of the melatonin in the body. Though melatonin has dramatic effects on the body for regulating circadian rhythms<sup>1</sup> and is also used therapeutically in cancer treatment, a lesser-known molecule known as DMT may be primarily responsible for these claims of importance placed on this small organ in the middle of the brain. The pineal gland’s production of DMT and DMT’s actions in the body are still relative mysteries though information is slowly becoming more available.

## Sinmoo Hapkido’s Biochemical Connection

Sinmoo Hapkido, a Korean martial art developed by Grandmaster Ji Han-Jae, places strong emphasis on mental and spiritual training. Ji talks extensively about the hormonal and biochemical correlations of his teaching and places a lot of emphasis on the adrenal stress response as a major component of generating

<sup>1</sup> Circadian rhythms are so-called body rhythms that allow the body to respond to environmental stimuli such as day and night.

power for use in martial application. Ji states that through proper training, one can control his or her responses to stress.<sup>2</sup> Epinephrine (adrenaline) and norepinephrine are released from the adrenal glands that lie above the kidneys. The hypothalamus and pituitary glands, which lie in the middle brain, stimulate these chemicals; they are released in a hormone cascade beginning in the hypothalamus.<sup>3</sup> Though an adequate explanation of how the middle brain affects some of the major physical reactions associated with a major sympathetic stress response, this does not address a number of the other properties of the middle brain as espoused by Ji's Sinmoo Hapkido and many other traditions that place importance on this part of the body. In addition to discussing epinephrine, Ji also talks about a so-called, super hormone that has the ability to stimulate these special actions attributed to the middle brain, such as an elevated consciousness and altered perception of time.

In Ji's opinion, through the meditative practices as he teaches, students can "open their third eye" and alter their perception of time. This altered perception can be used in martial arts situations, medical applications and treatment, and daily life. In martial applications, Ji says for offense the practices "make time fast," so strikes seem impossibly rapid. For defense, he says, they "make time slow," so that an incoming attack appears to move in slow motion. Anyone who has seen the movie *The Matrix* can visualize these concepts as portrayed in the fight scenes of that movie. Similarly, those who have had the unfortunate experience of a car accident likely experienced a change in perception of time, where everything moved in slow motion. In Ji's teaching, with proper training one can learn to work and respond in this seemingly altered time.

### **The Pineal Gland: The Biological Third Eye**

The pineal gland is a small reddish-gray gland about the size of a grain of rice and is found in the brain (Sumida, Barkovich, & Newton, 1996: 233-236).<sup>4</sup> Whereas most parts of the brain are divided in half—into the right and left hemispheres—the pineal gland straddles this division and sits alone in the area known as the middle brain. Though theories of its function are still largely speculative, the

<sup>2</sup> The stress response is governed by the parasympathetic and sympathetic actions of the autonomic nervous system.

<sup>3</sup> The hypothalamus is a neuroendocrine gland in the middle brain. It is ultimately responsible for maintaining homeostasis in the body, including the endocrine glands, blood pressure, and metabolism.

<sup>4</sup> The pineal gland or epiphysis, is a small neuroendocrine gland that is composed of "pinealocytes" and glial cells. During the seventh week of gestation, the cells that will become the pineal gland grow upward from the diencephalon and eventually come to rest on the midline at the caudal aspect of the third ventricle in the brain. The pineal gradually grows until about the second year of life where it reaches the average size of 7.4x6.9x2.5mm (Sumida et al., 1996: 233-36). Though the size does not change from ages two through twenty, the weight gradually increases from puberty to old age, likely due to the gradual calcification of the gland.

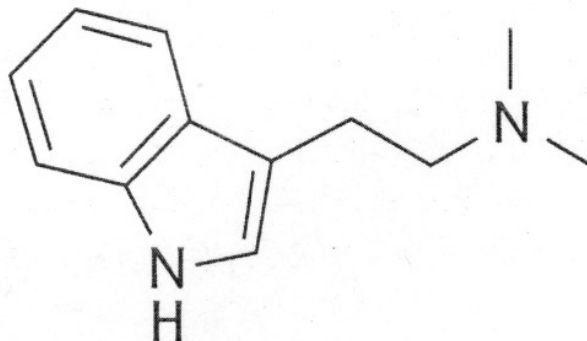
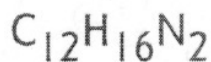
pineal gland's reactivity to light is one of the reasons it has earned the name "the third eye."

The gland is thought to be an actual primitive eye that has been modified through evolution. In some amphibians it still acts as an eye with direct physiological responses to light. In humans its influence may be less direct, as the majority of its function seems to be through the eyes. The retinas, once exposed to light, relay that information to the spinal cord, and then eventually back up to the brain (Bowen, 2007).<sup>5</sup> There is also some speculation that the pineal gland may react directly to sunlight without retinal stimulation since it has been shown that light does penetrate mammals' skulls. This is unlikely though, since rats that were experimentally blinded lost the ability to convert melatonin and thus react effectively to light-dark cues (Wurtma, Axelrod, & Kelly, 1965).

If however, light does penetrate directly, it can give importance to body positioning in relation to the sun as is often taught in meditative and martial training. In Sinmoo Hapkido the meditative exercises are to be done facing certain directions at various times of day, and elevation also plays a role in the effectiveness of the practice (Bradley, 2006: 76-89). Both direction and elevation are considered in relation to the sun, and this may be because of its influence on the pineal gland. This could also give practical application to shaving one's head, as is the tradition for many Buddhist monks, in whose training meditation is a major component.

In addition to light cues, the pineal gland also responds to temperature, mechanical, and magnetic stimuli (Wisneski & Anderson, 2005). Though there is no current research, these responses could potentially be affected by certain meditation exercises (i.e., chanting, qigong, mindfulness), trauma, hyper/hypothermia, and exposure to electromagnetic fields, such as those emitted from cell phones.

Dimethyltryptamine:  
A Super Molecule



<sup>5</sup> The retinas, which are in the back of the eye, are exposed to light, which is relayed to the suprachiasmatic nucleus of the hypothalamus (another area of the middle brain). Nerve fibers then descend the spinal cord to the superior cervical ganglion. From here, post-ganglionic neurons ascend to the pineal gland, thus relaying the light information (Bowen, 2007).



Dimethyltryptamine (DMT), or N-dimethyltryptamine (N), is a psychoactive substance that is endogenously produced by the pineal gland in small amounts (Karkkainen et al., 1995: 145-52).<sup>6</sup> It belongs to a class of molecules called tryptamines which include serotonin,<sup>7</sup> tryptophan,<sup>8</sup> and melatonin. Tryptamines are also the backbone of a number of psychoactive drugs, such as psilocybin, psilocin, and LSD. DMT does not stay in the system for very long and is broken down by monoamine oxidase (MAO).

DMT was first synthesized in 1931 by Canadian chemist Richard Manske. It remained unnoticed until psychedelics were explored in detail in the 1950s and 1960s, when a Hungarian pharmacologist, Stephen Szara, experimented on himself with various doses and recorded the psychedelic properties (Strassman, 1999: 183-94).

Most of the information currently available on DMT is from research conducted on the use of hallucinogenic plants in Latin America. *Ayahuasca*, *yage*, *nopa daime*, and *natema* are all names for DMT-containing concoctions used in shamanistic and ceremonial rituals throughout Central and South America. The most well know of these is actually a plant tea mixture called ayahuasca. Ayahuasca is most commonly composed of the leaves of *Psychotria viridis* and stems of *Banisteriopsis caapi* (Freedland & Mansbach, 1999: 183-94). The *Psychotria viridis* contains DMT and is used for its hallucinogenic properties. The *Banisteriopsis caapi* contains Beta-carboline harmine, which is a MAO inhibitor and therefore prevents the DMT from being broken down before the effects are felt (Ott, 2001: 403-7). If DMT is taken orally without a MAO inhibitor, the hallucinogenic effects are not seen. With the MAO inhibition, the first-pass metabolism is prevented, and DMT reaches the central nervous system and the systemic circulation (Riba et al., 2003: 73-83). This basically means that the plants will have no special effect unless they are used in combination and combined in a specific way. DMT has also been administered via IM injection,<sup>9</sup> though the duration of action is typically much shorter (Strassman et al., 1996: 784-95).

In 1965 DMT was isolated from human blood, and in 1972 it was found in human brain tissue. It is also found in urine and cerebrospinal fluid. In 1985

<sup>6</sup> It is formed from serotonin and tryptamine by the enzyme indolethylamine N-methyltransferase and is then rapidly catabolized or broken down by monoamine oxidase (MAO) (Karkkainen, 1995: 145-52).

<sup>7</sup> Serotonin (5-hydroxy-tryptamine) is a neurotransmitter that is involved in digestion and also in mood regulation. Modulating serotonin is a major role of many current antidepressants.

<sup>8</sup> Tryptophan (alpha-carboxytryptamine) is an essential amino acid, needed to make serotonin and other neurotransmitters.

<sup>9</sup> Intramuscular injection is when a substance is injected directly into a muscle.

Japanese scientists discovered that not only is DMT produced in the brain, but it is also actively transported across the blood-brain barrier and binds to serotonin receptors (Yani et al., n.d.). DMT is found in relatively high concentrations in the brain, but has also been isolated in lung and kidney tissues (Karkainen, 1995: 145-52).

According to recent research, DMT increases the binding of serotonin at certain sites in the brain (Smith et al., 1998: 323-30).<sup>10</sup> The central nervous system effects when this occurs include; excitation, anxiety, increased learning, behavior modifications, cerebrospinal fluid secretion and smooth muscle contraction (Gouzoulis-Mayfrank et al., 2005: 301-11).<sup>11</sup> DMT has also been demonstrated to increase blood pressure (Riba, 2003: 73-83).<sup>12</sup> Though these excitatory symptoms arise in some instances of administration of DMT, the effects are often the opposite and depressive or calming symptoms are observed. As these effects are far reaching, DMT is implicated in a number of disorders (Burchett & Hicks, 2006: 223-46).<sup>13</sup> This means that the actions of DMT seem to be largely situational, and by altering the environment may alter the body's response (Jacob & Presti, 2005: 930-37).

### **Sinmoo Hapkido Meditation and Ki Breathing<sup>14</sup>**

There are two broad categories of exercises in Sinmoo Hapkido that fall under meditation and ki breathing. The first is chanting and the second is breathing. Chanting exercises use either a mantra such as the well-known Buddhist mantra "Om ma ni pad me hum," or, more commonly, counting numbers. The first seated meditation exercise taught in Sinmoo Hapkido is called "concentration meditation" and involves simply counting out loud, backwards, from one hundred to one. While counting, the practitioner is encouraged to visualize the numbers in the area of the third eye to narrow one's focus for stimulation (Ji, personal interview 2007).

---

<sup>10</sup> DMT is a 5-HT<sub>2A</sub> and 5-HT<sub>2C</sub> agonist.

<sup>11</sup> In a recent study comparing DMT with Ketamine (an NMDA antagonist), the symptoms resembling positive symptoms of schizophrenia, such as positive formal thought disorder and inappropriate affect, were found in the DMT group. The Ketamine group exhibited catatonia and attention deficits, which are associated with the negative symptoms of schizophrenia (Gouzoulis-Mayfrank et al., 2005: 301-11).

<sup>12</sup> DMT has been demonstrated to increase both the systolic and diastolic blood pressures.

<sup>13</sup> DMT plays a significant role in G-protein-coupled receptors that are responsive to trace amines. Alterations in the function of these trace amine receptors are thought to be involved in the etiology of a number of disorders, such as schizophrenia, attention deficit hyperactivity disorder, obsessive-compulsive disorder, bipolar disorder, anxiety states, and major depression (Burchett, 2006: 223-46). DMT's activation of these receptors is hypothesized to cause the anxiolytic or amphetamine-like action that is often seen at low doses (Jacob & Presti, 2005: 930-37).

<sup>14</sup> Ki breathing refers to a broad range of exercises intended to build or move energy (Korean/Japanese, *ki*; Mandarin, *qi*). This topic is discussed more on subsequent pages.

Breathing exercises are as one would expect, exercises that focus on breath observation and control. The unique aspect of Sinmoo Hapkido breathing practices is the “press phase”: holding the breath, one bites down on the molars and clenches the jaw while pressing downward. By clenching down, and also through chanting, a vibration is created in the mouth and in the bones and tissue in the jaw and skull. This vibration creates a mechanical stimulation of the middle brain and potential release of the cascade of molecules. By mechanically stimulating the pineal gland it is possible to modulate the release of DMT for an altered stress response.

### **Sinmoo: Higher-Mind Martial Art**

When Ji developed his unique style of Hapkido, he decided to place more emphasis on the exercises listed above, in addition to a philosophical framework in which to fit the practice. Though still having hundreds of physical techniques—kicking, striking, weapons, joint locking and throwing—Sinmoo Hapkido places a greater emphasis on meditation, ki breathing exercises, and philosophy.

*Hapkido* is often translated as “the way of coordinating power,” which clearly places emphasis on the physical techniques the art is often known for. Ji gives a slightly different explanation. “*Hap*” means bringing together, gathering, or harmonizing. “*Ki*” is the energy or breath in the body that connects the mind and the body (Li, 2008: 194-212).<sup>15</sup> “*Do*” simply means the process or way of life. Hapkido, then, means “the way of harmonizing the mind and body through the utilization of ki.”

Sinmoo is the specific style of Hapkido that Ji teaches. *Moo* means martial art. *Sin* has a number of meanings, but Ji’s intended meaning is a “higher level, higher mind, or higher spirit.” His original translation used, “God-like,” and because his English was very poor at the time, the meaning became misunderstood. The first *hanja* character Ji used for *sin* was the same used in much of Chinese philosophical tradition and traditional Chinese medicine.<sup>16</sup> Ji later changed to an ancient character shown below that is no longer used in modern

---

<sup>15</sup> *Ki* (Korean; Mandarin, *qi*) is often translated in modern texts as “energy,” and older texts as “breath.” The character is made up of two parts. The first is *mi*, which means rice. The second part means vapor. *Ki* has a number of different meanings in numerous fields, from physics and psychology to medicine and martial arts. Depending on the context, the meaning changes. In this context we use *ki* to describe an energy or concept that exists in the body and creates a physical action out of an idea, hence bringing the mind and body together. It should be noted that the physiological phenomenon being discussed in this article falls under this concept of *ki* (Li, 2008: 194-212).

<sup>16</sup> *Hanja* refers to the Chinese characters incorporated into the Korean language with Korean pronunciation.

language (Ji, personal interview, 2009). The character for *sin* can also be used to

language (Ji, personal interview, 2009). The character for *sin* can also be used to refer to ghosts or spirits, which is not the meaning he intended. The intended meaning of *sin* is easiest to understand as “a higher, more enlightened state of existence.”

	Sin	Moo	Hap	Ki	Do
k o r e a n	신	무	합	기	도
c h i n e s e	神 <small>ancient form</small>	武	合	氣	道



When translated in its entirety, Sinmoo Hapkido means “the way of using martial arts to harmonize the mind and body to reach a higher, more enlightened state of existence.” Using this translation as the foundation and entire purpose of the martial art, it is possible to see how the practices mentioned above and potential biochemical reactions in the body and mind may lead to the ultimate goal.

### Theoretical Applications in Medicine and Martial Arts

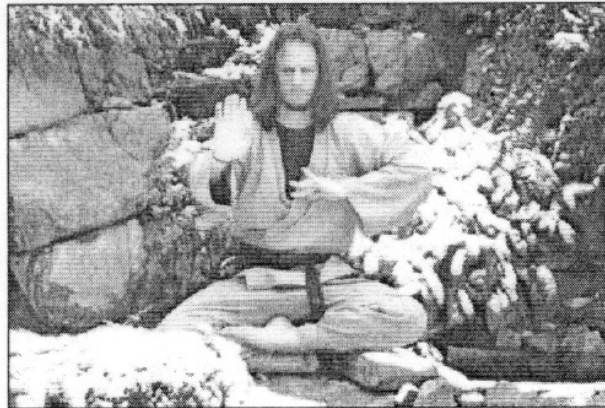
Though there may be potential for the reintroduction of psychedelics for treatment of a number of disorders and to reach certain levels of training, DMT is still considered a controlled substance. There may be better, safer, more natural, and longer-lasting methods to achieve the desired results utilizing this pathway. Though there are very few measurable effects of DMT, such as blood-pressure elevation, ayahuasca, one of the plant combinations mentioned above that contains DMT, has been shown to activate the cerebral cortex (forebrain) and limbic structures (middle brain) on MRI (Riba et al, 2004: 89-101). With substances containing DMT there is also an increase in blood flow to the area of the middle brain (Riba, 2006: 93-98).<sup>17</sup>

<sup>17</sup> Increased blood perfusion has been found to increase in the anterior insula, the anterior cingulate cortex, and the left amygdala/parahippocampal gyrus, which are all parts of the middle brain (Riba et al., 2006: 93-98).



These activated areas of the brain are associated with somatic awareness, subjective feeling states, and emotional arousal, which is in line with the subjective experiences reported by users of DMT. Some of the common experiences reported with DMT use are:

- euphoria
- anxiety
- alternate realities
- colored hallucinations
- enhanced creativity
- enhanced emotional states
- auditory hallucinations
- clouding of consciousness
- timelessness or loss of time-and-space reality
- coexistence of opposites (i.e., life and death, good and evil)
- knowledge that life continues after death
- sense of wisdom or love pervading all existence
- communicating with alien life forms or gods



*Photograph  
by Yi-Pei Lin.*

DMT is increased with the rise in catecholamines, or hormones, during stress, and it is hypothesized that DMT may be released from the pineal gland in large amounts at extremely stressful periods. Some of these experiences include birth, near-death experiences, and psychosis, and may be important in deep meditation or spiritual practices. If we are under constant stress and catecholamines are elevated there is likely to be a decrease in production of DMT over time due to negative feedback and up-regulation of MAO.

As Staussman, the leader in DMT research, theorizes: “Pineal DMT production is the physical representation of non-material, or energetic, processes. It provides us with the vehicle to consciously experience the movement of our life-force in its most extreme manifestations” (Strassman, 2001: 68). It is interesting to note the similarities in language that Staussman uses and the potential connection to “*ki*” as discussed earlier.

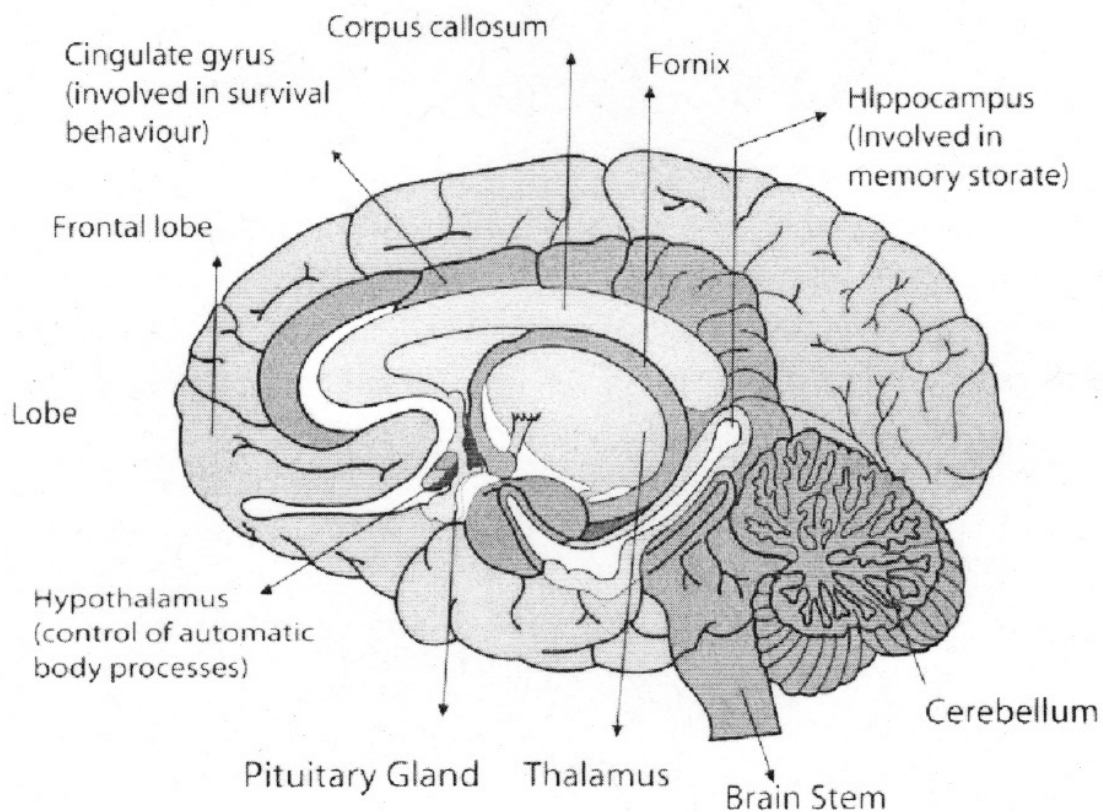
DMT is tightly regulated within the brain.<sup>18</sup> If the molecule is not produced optimally, it is possible that when extremely stressful situations arise the person will not be able to appropriately deal with the situation due to a lack of

<sup>18</sup> This is largely due to the rapid breakdown of DMT by MAO. There is also relatively low activity of the enzyme indolethylamine N-methyltransferase that creates DMT.

DMT. In situations such as chronic stress, depression, and post-traumatic stress disorder, individuals may not be able to appropriately make the mental or spiritual connections that could be prompted by DMT release. An appropriate DMT release could modulate stress and help individuals overcome difficult situations.

As discussed above, it may also be possible that stimulating the pineal gland can trigger DMT release. This has been hypothesized with the application of transcerebral weak complex magnetic fields that induced DMT-like mystical experiences (Hill & Persinger, 2003: 1049-50). This may also be how meditative and spiritual practices induce these experiences. A number of other practices, such as qigong, acupuncture, and yoga, have meditative practices or treatments that aim at stimulating this point to attain certain milestones or create specific responses.

As mentioned above, Sinmoo Hapkido teaches chanting meditations and visualization techniques aimed at mechanically stimulating the third eye in order to change the perception of time (Ji, personal interview June 25, 2007). Qigong calls this point the upper dantian and uses it to generate and move energy in and potentially around the body. In yoga there is a *chakra* (energy center) located at the level of the third eye, which is also associated with time perception. It is possible that these practices aim to stimulate the pineal gland to release DMT, thus inducing a psychedelic experience to help overcome a spiritual block or reach another level of training.



## Conclusion: Martial Arts to Higher Mind

Though the research on DMT and the pineal gland is still in its infancy, if these theories prove true, they could explain physiologically the experiences from practices such as those in Sinmoo Hapkido. More research needs to be done, but having a physiological base in these practices could potentially help practitioners tailor training to help students decrease anxiety, make spiritual connections, give greater meaning to events, and overcome mental, physical, and spiritual stressors. By training to alter one's perception of time and manage one's stress response, it is also conceivable to reach a so-called higher level of martial arts and expanded ability. DMT could be the physiological pathway that explains how using martial arts to harmonize the mind and body and make efficient use of this metabolic pathway can lead one to reach a higher, more enlightened state of existence.



## BIBLIOGRAPHY

- BOWEN, R. (2007, November 10). The pineal gland and melatonin. <http://www.vivo.colostate.edu/hbooks/pathphys/endocrine/otherendo/pineal.html>. Accessed November 10, 2007.
- BRADLEY, S. (2006). Cultivating the elixir field with Sinmoo Hapkido's danjun breathing. *Journal of Asian Martial Arts*, 15(3): 76-89.
- BURCHETT, S., AND HICKS T. (2006). The mysterious trace amines: Protean neuromodulators of synaptic transmission in mammalian brain. *Progress in Neurobiology*, 79: 223-46.
- FREEDLAND, C., AND MANSBACH, R. (1999 May 3). Behavioral profile of constituents in ayahuasca, an Amazonian psychoactive plant mixture. *Drug Alcohol Dependence*, 54(3):183-94.
- GOUZOULIS-MAYFRANK E., HEEKEREN K., NEUKIRCH A., STOLL M., STOCK C., OBRADOVIC M., AND KOVAR K. (2005). Psychological effects of (S)-Ketamine and N, N-Dimethyltryptamine (DMT): A double-blind, crossover study in healthy volunteers. *Pharmacopsychiatry*, 38: 301-11.
- HILL D., AND PERSINGER M. (2003). Application of transcerebral, weak (1 microT) complex magnetic fields and mystical experiences: Are they generated by field-induced dimethyltryptamine release from the pineal organ? *Perceptual and Motor Skills*, 97: 1049-50.
- JACOB M., AND PRESTI D. (2005). Endogenous psychoactive tryptamines reconsidered: An anxiolytic role for dimethyltryptamine. *Medical Hypotheses*, 64: 930-37.

- JI, H. (2007, June 25). Personal interview. Cancun, Mexico.
- JI, H. (2009, September 17). Personal interview. Seattle, WA.
- KÄRKKÄINEN J., RÄISÄNEN M., HUTTUNEN M., KALLIO E., NAUKKARINEN H., AND VIRKKUNEN M. (1995, September 29). Urinary excretion of bufotenin (N,N-dimethyl-5-hydroxytryptamine) is increased in suspicious violent offenders: a confirmatory study. *Psychiatry Research*, 58(2): 145-52.
- LI, CUNSHAN (2008). A differentiation of the meaning of 'qi' on several levels. *Frontiers of Philosophy in China*, 3(2): 194-212.
- OTT, J. (2001, October-December). Pharmepéna-Psychonautics: Human intranasal, sublingual and oral pharmacology of 5-methoxy-N,N-dimethyl-tryptamine. *Journal of Psychoactive Drugs*, 33(4): 403-7.
- RIBA, J., ANDERER, P., JANE, F., SALETU, B., AND BARBANOJ, M. (2004). Effects of the South American psychoactive beverage ayahuasca on regional brain electrical activity in humans: A functional neuroimaging study using low-resolution electromagnetic tomography. *Neuropsychobiology*, 50(1): 89-101.
- RIBA, J., VALLE, M., URBANO, G., YRITIA, M., MORTE, A., AND BARBANOJ M. (2003, July). Human pharmacology of ayahuasca: subjective and cardiovascular effects, monoamine metabolite excretion, and pharmacokinetics. *Journal of Pharmacology Pharmacology and Experimental Therapeutics*, 306(1): 73-83.
- RIBA, J., ROMERO, S., GRASA, E., MENA, E., CARRIO, I., AND BARBANOJ, M. (2006). Increased frontal and paralimbic activation following ayahuasca, the pan-amazonian inebriant. *Psychopharmacology*, 186: 93-98.
- SMITH, R., CANTON, H., BARRETT, R., AND SANDERS-BUSH, E. (1998, November). Agonist properties of N,N-dimethyltryptamine at serotonin 5-HT<sub>2A</sub> and 5-HT<sub>2C</sub> receptors. *Pharmacology Biochemistry and Behavior*, 61(3): 323-30
- STRASSMAN, R. (2001). *DMT: The spirit molecule*. Rochester, NY: Park Street.
- STRASSMAN, R., QUALLS, C., AND BERG, L. (1996, May 1). Differential tolerance to biological and subjective effects of four closely spaced doses of N,N-dimethyltryptamine in humans. *Biological Psychiatry*, 39(9): 784-95.
- SUMIDA, M., BARKOVICH, A., & NEWTON, T. (1996). Development of the pineal gland: Measurement with MR. *American Journal of Neuroradiology*, 17: 233-36.
- WISNESKI L, ANDERSON L. (2005). *The scientific basis of integrative medicine*. Boca Raton, FL: CRC Press.
- WURTMAN R., AXELROD J., KELLY D. (1965). *The pineal*. NY: Academic Press.
- YANI, K., IDO, T., ISHIWATA, K., HATAZAWA, J., TAKAHASHI, T., IWATA, R., AND MATSUZAWA, T. (1986). In vivo kinetics and displacement study of a carbon-11-labeled hallucinogen, N,N-[11C]dimethyltryptamine. *European Journal of Nuclear Medicine and Molecular Imaging*, 12(3): 141-146.