The Pineal Gland: Master Gland and Interface.
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Introduction

Did you know that the tiny pineal gland, in the center of our brain, is the master gland? The pineal gland is a hormone producing gland as well as a neural structure. Most brain structures are paired, meaning that there is a left and a right one, yet the pineal gland is single. In school you may have learnt that the pituitary gland, also located in the brain just a few centimeters in front of and below the pineal is the master gland, regulating all other hormone glands in the body. However, the more science discovers about the pineal gland, the more clear it becomes that this is the real master gland. The pineal does not only play this role, but is also an interface between our environment and the inside of our body. Moreover, the pineal is an interface between our inner world of experience and our physical world, the latter encompassing our body as well as our environment. How is the pineal gland able to perform all these functions? Let us see how central and important our pineal gland is. Can we let the pineal work for us consciously? Yes! Learn how it can support our inner development.

The pineal as master hormone gland

The pineal gland is a very small structure. In humans it weighs only 50-150 milligrams (a milligram is one thousandth, 1/1000 of a gram) and is 7 mm in length and 5 mm in width, about the size of a cooked, swollen grain of rice [Wisneski et al. 2009]. You can find your pineal gland at the intersection of the following three straight lines: 1) the line connecting the upper attachments of your two ears, 2) the line connecting the point in between your eyebrows and the point about 2 inches (5 cm) above the center of the skull ridge at the back of your head, 3). The pituitary is situated just behind and above the nasal cavity, in between your temples (Figure 1). The pineal gland's name derives from the Latin word 'pinea' or pinecone, because of its pinecone-like shape.

http://upload.wikimedia.org/wikipedia/commons/6/6d/Pineal_gland.gif
Figure one: location of the pineal gland (highlighted in red) in the human head. from Anatomography, website maintained by Life Science Databases(LSDB), 20 September 2009. This file is licensed under the Creative Commons Attribution-Share Alike 2.1 Japan license.
[INTERNET WIZ, PLEASE INSERT THIS FREE ANIMATION INTO THIS ARTICLE]

The pineal gland is a hollow, single structure consisting of a pine cone shaped part that is connected to the brain by a left and right hollow 'stem'. The pineal gland is the only structure of the brain without a blood-brain barrier thus is in direct contact with the brain cavities as well as the blood circulation. The hollow stem of the pineal connects it to the brain cavity that is most centrally located in the brain and known as the third brain ventricle. The pineal gland protrudes into a blood sinus. The pineal gland is filled with cerebrospinal fluid and surrounded by blood [Reiter et al. 1977, Wurtman et al. 1968]. The cells of the pineal gland or the pinealocytes are neurons as well as endocrine cells. That the pinealocytes are neurons means that they are able to receive and send electrical signals, like those that are used all over the brain for communication among neurons. That the pinealocytes are endocrine cells mean that they are able to produce and secrete hormones. The body uses hormones as one of its means of communication. In the case of the pineal, secretion means that its hormones are sent into the blood and into the cerebrospinal fluid, the clear fluid, which fills the cavities of the

brain and the spinal cord. All other endocrine glands send their hormones only into the blood. Membrane receptors for pineal hormone molecules can de found all over the brain and the rest of the body. This means: in all these places cells are sensitive to the pineal hormones. The cells of the pineal are also sensitive to hormones from other hormone glands. Receptors for these have been found in the cell membranes of pinealocytes. Thus the pineal gland sends and receives neuroelectrical signals and secretes and receives hormones [Quay 1974].

The pineal gland regulates all other endocrine (i.e. hormone producing) glands and almost all body systems. Many complex interaction systems have been found between the pineal gland hormones and other hormone glands and also between their hormones and the pineal gland. Through these interaction systems the hormone glands, including the pineal, regulate each other's hormone-production. The hormones produced by the pineal gland also regulate other body systems. The pineal hormone melatonin, for example, stimulates the immune system and inhibits many other body systems, like the stress system [Reiter 1993a, Wisneski et al. 2009].

The pineal gland as an interface between body and environment

The pineal gland is our contact portal with the outer world, regulating body rhythms and the alternation between sleep and wakefulness [Quay 1974, Reiter 1977, 1991]. How does such a small gland, buried deep within the brain do this?

Our senses receive signals from the environment, translate these into electrical signals and send these to the brain for further processing. However, the pineal gland has its own nerve connections to the sense organs, which run through the spinal cord. Science knows the pineal gland is connected in this way to the eyes, ears and nose. The connection with the eyes is known in detail, those with the other senses still have to be clarified, as do the functions of these connections [Reiter 1977, Wisneski et al. 2009, Wurtman 1968]. Two different nerve connections inform the pineal gland about light and darkness: a fast connection and a slow connection. See Figure 2 for the anatomical structures. The slow connection informs the pineal about the rhythm of day and night and the changes in the length of the days throughout the seasons. Its nerve connections run from the retinas in the eyes through the optical nerves, hypothalamus, to the upper ganglia on either side of the cervical spine (near the top of the neck) to the pineal. Based on the light-dark rhythm the pineal gland hormones melatonin and serotonin set our biological clock, the suprachiasmatic nucleus (SCN), which is a group of neurons just above the optic chiasm. Its name 'suprachiasmatic' means 'on top of the chiasm'. The pineal uses external light and darkness to entrain the body to daily and seasonal rhythms of the sleep-wake cycle and all its accompanying fluctuations, like those in metabolism, blood pressure, core temperature and hormone levels [Reiter 1977, Wisneski et al. 2009]. These are called 'circadian rhythms'. A circadian rhythm is an endogenously driven roughly 24-hour cycle in biochemical, physiological, or behavioural processes. The term "circadian" comes from the Latin circa, meaning 'around', and diem or dies, meaning 'day'. When we fly through several time zones to the East or West, we may initially have a 'jet lag'. This is corrected by the biological clock, after it is corrected by the pineal gland, which is informed by the eyes about the shift in light-dark cycle. Most blind individuals have an unusual circadian rhythm or a free-running rhythm with a consistent delay of about 60 to 70 minutes a day. However, melatonin production is not impaired in blind people. People with a free-running rhythm will be sleepy during the day for half of the month and during the night for the other half of the month [Lewy et al. 1983, Sack et al. 1992].

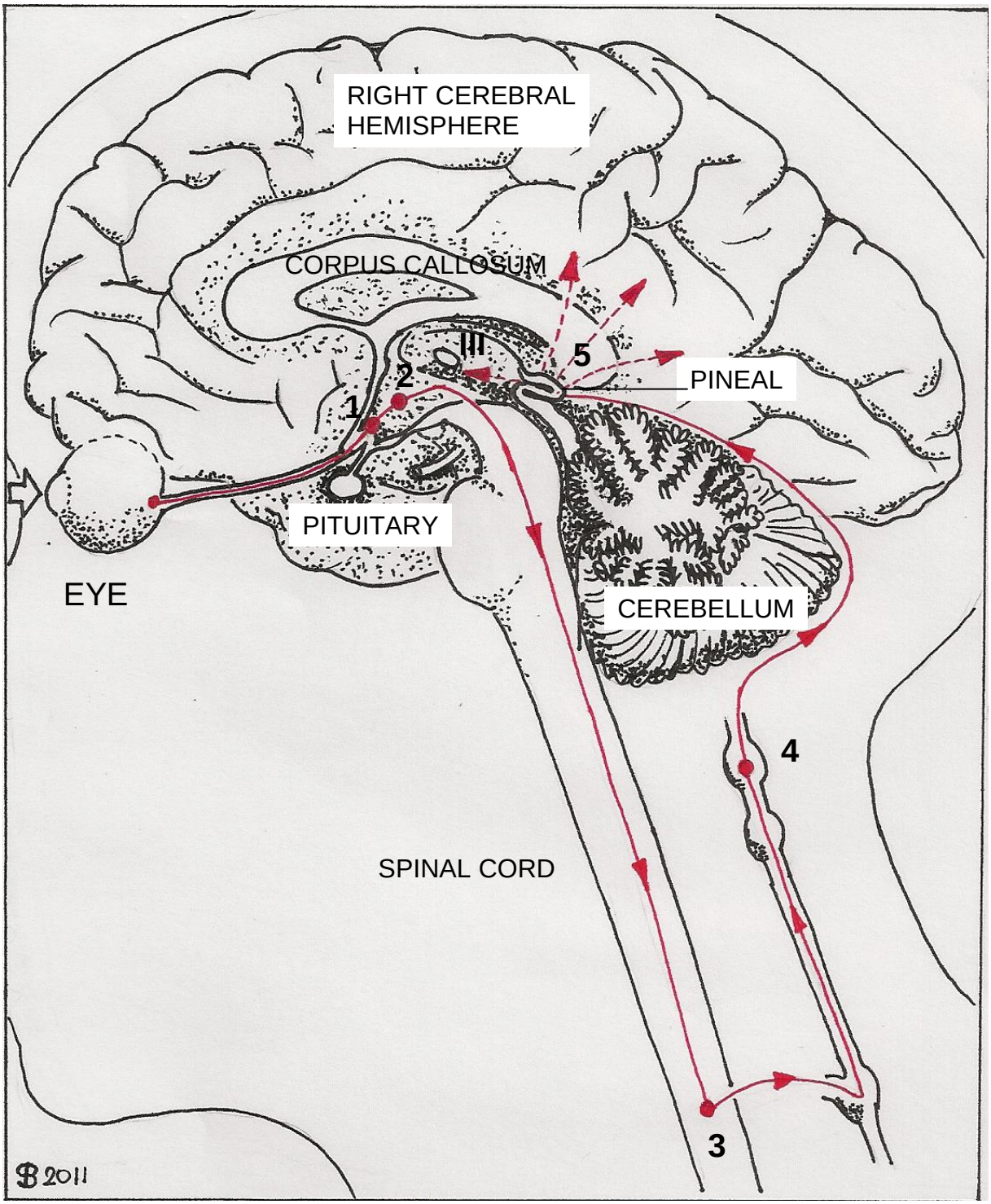

Figure 2 – Location of the pineal gland in the human brain. This is a view on the inside of the right brain. The front of the head is on the left, its back on the right side of the figure. The pineal is attached to the epithalamus, or roof of the thalamus. As a hollow structure the pineal is connected to the third brain ventricle (III). The pituitary protrudes from the hypothalamus, or bottom of the thalamus. The optic chiasm is just below the number 1. The suprachiasmatic nucleus or SCN (No. 1) is just above the optic chiasm. The pathway (highlighted in red) from the eyes to the pineal runs through 1) the suprachiasmatic nucleus, 2) the paraventricular nucleus, 3) the spinal cord, 4) superior cervical ganglion, ending in 5) the pineal gland, which produces (red arrows) melatonin on inhibition (darkness) and serotonin on stimulation (light). (Illustration by the author).

Through the fast connection the pineal receives information about fast light phenomena, like lightning flashes. From the eyes to the hypothalamus the nerve connection follows the same route as in the slow system, however, it then runs from the back of the corpus callosum to the pineal [Reiter 1977, Wurtman 1968]..

The pineal gland is not only sensitive to light, sound and smell, yet also to fluctuating magnetic fields, like the 50 or 60 Hertz magnetic field from the electrical mains (Redecke 1999, Reiter 1993b). How the magnetic sensitivity of the pineal works is still unknown, but the microscopic magnetite crystals inside the pinealocytes (an in neurons all over the brain) may have something to do with it as may the piezoelectric component of the pinealocyte's crystal population [Kirschvink et al. 1992, Kobayashi et al. 1995]. The piezoelectric crystals inside the pineal gland cells are possibly hydroxyapatite and an unusual crystal form of calcite [Lang et al. 1996, Baconnier et al. 2002].

The pineal thus is an interface between environment and body. The pineal is also an energy transducer. A transducer in a technical sense is a device that converts one form of energy into another, for example a solar panel cell that converts the light from the sun into electricity . Our senses transduce environmental signals (like light, smell, temperature and sound) to electrical signals. The pineal gland transduces these electrical signals to hormone signals, often in the form of melatonin that can change the course of the body's functioning [Wisneski et al. 2009], and it may be able (the author's hypothesis) to transduce received hormones from other endocrine glands to electrical signals.

Importance of the pineal for our health

A healthy pineal will be able to fulfill all of its functions, from the biological to the inner, psychological ones. In this paragraph you may find helpful ideas for supporting your pineal's health.

Too much as well as too little light can lead to depression. In normal life, with light-dark and seasonal cycles, a shortage of daylight can cause too much melatonin in the blood at daytime, bringing the daily body rhythm out of sync with the sun, which may cause autumn or winter depression [Lewy et al. 2006]. On the other hand, a shortage of darkness thus an overexposure to artificial light can lead to a shortage of melatonin. Melatonin is also important for stimulation of the immune system. Shortage of it may contribute to Chronic Fatigue Syndrome (CFS) and other immune deficiency related diseases. Shortage of melatonin may also disturb the body's circadian rhythm. Symptoms of CFS can also be anxiety and depression [Doljansky et al. 2005]. Thus a shortage as well as too much melatonin in the body can contribute to these symptoms.

The hormone melatonin from the pineal has an inhibiting regulatory effect on all body systems which are sensitive to it, but stimulates the immune system [Wisneski et al. 2009].

Melatonin works as an antioxidant. Melatonin is also a scavenger of free radicals like highly reactive oxygen in our cells and thus contributes to the prevention of cancer and fast ageing [Reiter 1995]. A balanced thus properly functioning pineal, producing balanced melatonin levels, may even have a rejuvenating effect on the body. We produce balanced levels of melatonin when we prevent underexposure as well as overexposure of ourselves to light [Doljansky et al. 2005, Lewy et al. 2006, Reiter 1995].

All pineal hormones are derived from the amino acid tryptophan, which we obtain from food. It is useful to know which foods have lots of tryptophan. The amino acid tryptophan is the basic substance for all hormones of the pineal gland, which will be discussed below. Tryptophan is not produced by the human body. It is an essential amino acid, which means it needs to be taken in from the food. It can be found especially in pumpkin seeds, lentils, bananas, dates, cottage cheese, eggs, grains, brown rice, sesame seeds, sunflower seeds, peanuts and other nuts. Tryptophan is taken up really well by the brain, when these foods are eaten with something sweet, like a bit of honey. These foods may assist in falling asleep more easily and in soothing nerves and anxiety (see also the Vitamins & health supplements guide, URL in the reference list below) [Wurtman et al. 1980].

As mentioned in the paragraph above, the pineal gland is sensitive to fluctuating magnetic fields. A melatonin shortage can occur when people sleep near devices (like alarm clocks, lamps, telephone chargers, electric blankets) that are connected to the electrical mains and thus have a 50 or 60 Hertz magnetic field around them [Redecke 1999, Reiter 1993b]. The lack of melatonin may cause a lack of sleep. Thus it may be helpful, if possible, to avoid electrical devices on, in and around our bed.

Besides magnetite crystals, the pinealocytes also contain microscopic crystals of calcite and hydroxyapatite, the crystals that are abundant in bones and teeth. The calcite and hydroxyapatite are inside the pinealocytes in the form of layered balls, consisting of 20 x 200 nm (nanometers, 1 nanometer is 1 billionth of a meter) crystals [Galliani et al 1989] up to 20 µm (micron or one millionth of a meter) long crystals [Lang et al. 1996]. These balls and their layers can be viewed through a microscope, after dyeing them [Galliani et al 1989]. These balls of crystals can grow, stay the same or diminish in size and science does not know why [Galliani et al 1989]. The growing crystal aggregations can cause the pineal gland to calcify [Galliani et al 1989]. In the human the degree of calcification can be observed on a CT (computed tomography) scan [Bayliss 1985]. A study using this method revealed that the probability of pineal calcification increased with age. Studies of radiographs and computed tomography show on living humans that calcification begins in childhood, that 53 % of young adults and 83 % of elderly individuals have a calcifying pineal gland [Old et al. 1974]. The more the pineal is calcified, the less melatonin is found in the urine [Kunz et al. 1999] and the more daytime tiredness and sleep disturbance one has [Kunz et al. 1998]. Pineal calcification is also correlated with a poor sense of direction in humans [Bayliss et al. 1985]. This has also been found in homing pigeons [Bayliss et al. 1985]. Their pineal is 10 % of their brain weight, in humans less than 1 %. Could the sense of direction have something to do with (direct or indirect) magnetic field perception by the pineal? According to research at the California Institute of Technology microscopic crystals of magnetite can be found in cells all over the brain, not only in the pineal [Kirschvink et al. 1992, Kobayashi et al. 1995]. Wisneski and Anderson (2009) suggest that perhaps, researchers should begin to study the correlation between pineal calcification and senility. However, the correlation between age and pineal calcification is not shared by all research groups [Galliani et al 1989, Tapp et al. 1972]. For decalcifying the pineal various remedies are available like the Ayurvedic remedy Shilajit [Agarwal et al. 2007].

The pineal gland as an interface between inner and outer world

According to various spiritual traditions the pineal gland is an interface between the inner world of experience and the material world, the latter consisting of our body and our environment. This is supported by certain scientific findings [Wisneski et al. 2009].

In Tibetan Tantrism and in Yoga the pineal gland is often associated with the crown chakra and sometimes with the forehead chakra, which is also called the 'third eye'. Chakras are described in Eastern religious and medical systems as parts of the human subtle energy field and connected to the physical body. Chakras are described as transducers for subtle energy [Wisneski et al. 2009]. Wisneski and Anderson (2009) speculate chakras are energetic portals that permit a subtler yet profoundly sustaining energy to enter the body. They speculate further that the seven main chakras each open and connect into nerve plexus of the autonomic nervous system, interacting richly with the endocrine system. The seventh (crown) chakra, which they consider to be connected to the pineal, would connect to the autonomic nervous system through the central nervous system [Gerber 1988, Wisneski et al. 2009]. In Eastern traditions, the sixth or brow chakra is associated with intuitive insight and clairvoyance, the seventh or crown chakra is associated with deep inner searching, the so-called 'spiritual quest' [Gerber 1988]. Eastern religions also describe the pineal itself: we have our two eyes and the mysterious third eye is the pineal, the seat of wisdom or the source of inner light. The association of the pineal with spirituality has probably been the reason why this gland has not been attractive for serious scientific research until the 1970-s, a time that masses of people and also some scientists became interested in Eastern religion [Zrenner 1985].

Also scientifically the pineal gland is associated with a 'third eye'. According to evolution biology the pineal gland has been a third eye on top of the head of vertebrates until 240 million years ago (the time of the dinosaurs), in between the two eyes that are located at the sides of the head [Ariens Kappers 1981, Wisneski et al. 2009]. Some invertebrates like some fish, salamanders, lampreys, crocodiles and lizards (like the Tuatara in New Zealand) still have a thin spot of bone or even a hole in the skull in between their two lateral eyes. Their pineal gland has a part inside the brain from which a thin nerve runs to this point, ending in a structure named "pineal eye", which sits right under the thin part in the skull or under the skin. The pineal eye contains light sensitive cells, may even have a lens and receives information directly about the natural light-dark cycle. It serves to regulate the circadian and seasonal rhythm of the animal. In more complex species of animals the pineal is completely inside the brain and connected to the eyes through nerve pathways. These pineal glands are indirectly sensitive to the natural light-dark cycle and are informed about it by the eyes. Interesting is that the human embryo in its first weeks forms a pineal eye, which extends to the forehead and then it is retracted into the center of the brain and integrated into the part of the pineal gland at that location [Ariens Kappers 1981]. In the human embryo some of the pigmented cells of the pineal are arranged in a rosette-like structure reminiscent of developing retinal structures [Min et al. 1987].

Also in the Western world the pineal gland has been associated with spirituality. The philosopher/scientist René Descartes (1596-1650) from France, who lived and worked in The Netherlands part of his life, called the pineal 'seat of the soul'. 'Seat of the soul' is often misunderstood [Wisneski et al. 2009]. Descartes did not think the pineal was the location of the soul, but the interface between the spiritual and material worlds. This fitted nicely in his dualistic philosophical system, which dived the universe into mutually exclusive but interacting elements of spirit/mind/God and of matter. Descartes wrote on 29th January 1640:

“My view is that this gland is the principal seat of the soul, and the place in which all our thoughts are formed. The reason I believe this is that I cannot find any part of the brain, except this, which is not double. Since we see only one thing with two eyes, and hear only one voice with two ears, and in short have never more than one thought at a time, it must necessarily be the case that the impressions which enter by the two eyes or by the two ears, and so on, unite with each other in some part of the body before being considered by the soul. Now it is impossible to find any such place in the whole head except this gland; moreover it is situated in the most suitable possible place for this purpose, in the middle of all the concavities; and it is supported and surrounded by the little branches of the carotid arteries which bring the spirits into the brain” [Adam et al. 1964-1974, Cottingham et al. 1984, 1991].

The pinealocytes produce 6 different hormones from the amino acid tryptophan, that we obtain from food. The 6 hormones from the pineal gland enable us to experience different states of consciousness, by interaction with the brain (and possibly also the rest of the body): waking, sleeping and various meditative and visionary states of consciousness. Below (Figure 3) is a diagram that shows the names of the pineal gland hormones and in what sequence they are derived from tryptophan and from each other.

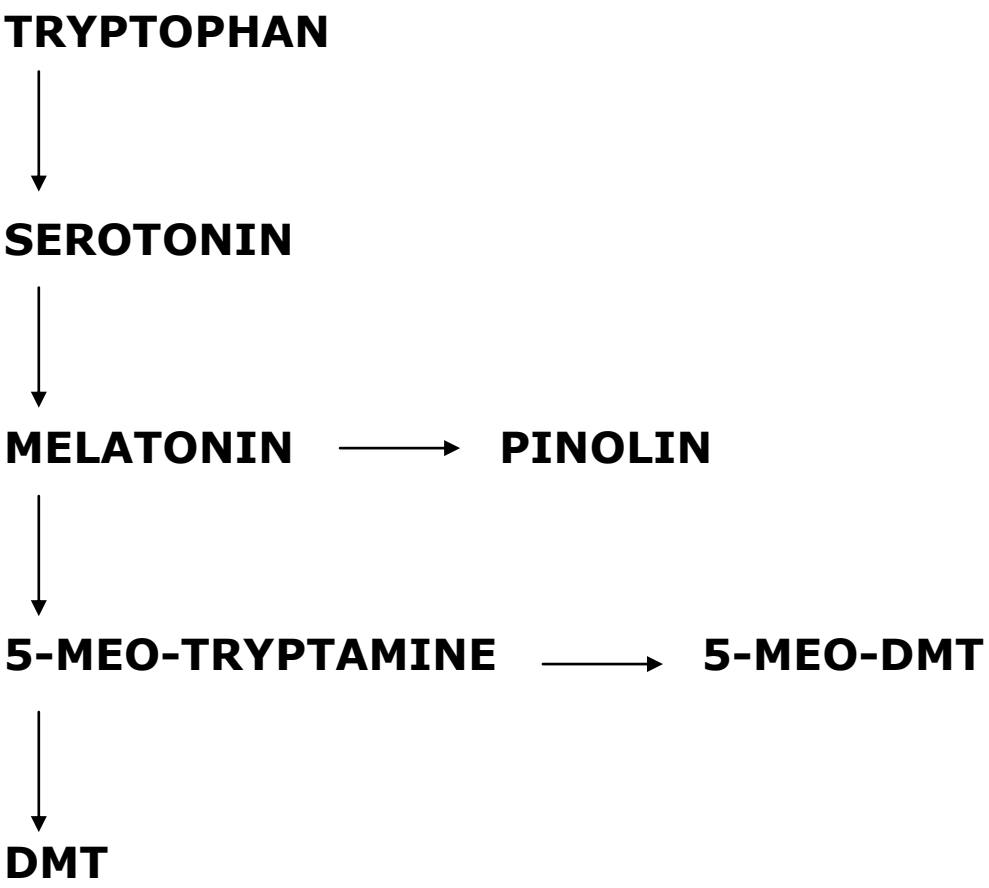

Figure 3 - diagram of the conversion of tryptophan into different pineal gland hormones.

At daytime the pineal gland is stimulated by the daylight to produce serotonin, which keeps us awake and alert: waking consciousness. Serotonin is also a calming neurotransmitter when present at moderate levels [Wurtman et al. 1980]. In waking consciousness one can think

clear and rationally and interact consciously with the (social) environment. When one closes the eyes and relaxes deeply like in some forms of meditation or falls asleep, other pineal hormones will appear on the scene.

As soon as darkness sets in the pineal converts serotonin into melatonin (*N*-acetyl-5-methoxytryptamine). Melatonin is highly lipophilic, which means it dissolves better in oil than in water. As cell membranes consist of an oily substance, this means that melatonin easily passes out of the pineal via cell membranes. Melatonin is found in many body fluids, like blood, cerebral spinal fluid, saliva and urine. As mentioned before melatonin influences many different cells in the body, not only in the brain. It can do so by binding to a receptor in the outer membrane of the cell [Stankov et al. 1990] or by binding to a receptor in the membrane of the cell nucleus [Wiesenberg et al. 1995, Carlberg 2000]. Melatonin causes our thinking to become less clear: we become sleepy and then we fall asleep. Just before the dream phase it is converted into other hormones (see next paragraphs). In a 7 to 8 hour night of sleep we go through 4 to 6 sleep stages and we dream 4 to 6 times. However, we don't dream on melatonin. However, melatonin is also secreted during meditation [Tooley et al. 2000], yet we don't have our meditation experiences on melatonin.

According to James Callaway (1988) melatonin is converted into pinolin, DMT (*N*,*N*-dimethyltryptamine) and 5-meo-DMT (5-methoxy-dimethyltryptamine) just before REM sleep (the dream phase). Because of their specific psycho-activity these hormones make it possible for us to have spontaneous, inner experiences, called dreams. Thoughts and emotions can be part of the dreams. It is possible that DMT is secreted by the pineal during deeper states of meditation [Wisneski et al. 2009].

If one of these three hormones is produced in wakefulness during meditation, we may have spontaneous inner experiences, for example a flash of insight. This state of consciousness is called "reverie" as it is often accompanied by spontaneously emerging, inner experiences, while the person stays detached from these. Reverie is known to have a psychologically integrating effect and is used in psychotherapy [Green, 1989]. It is also known that some scientists, like August Kékulé von Stradowitz and Albert Einstein, got their brilliant flashes of insight in this state of consciousness. In this way Kékulé found the ring structure of benzene and Einstein his General Theory of Relativity. The spontaneous inner experience may also be a deep feeling of oneness with all existence, like meditators from Eastern and Western traditions may experience [Green, 1989].

Rick Strassman in the USA has studied the effects of intravenously injected DMT. With healthy, adult subjects he has performed research on the experiences they had after administration of DMT. He chose to inject DMT intravenously, because this would allow a better control of its blood level than ingesting or smoking DMT would do. The subjects, who were in a bed in a hospital during these experiments, reported a broad range of experiences. The experience usually started with seeing light, colours and geometrical shapes and hearing high-pitched sounds, followed by seeing and hearing bizarre beings and machines. The experience culminated in the sensation of journeying outside the body into other realities, interacting with these. Some volunteers even described near-death experiences and clairvoyance in space and time [Strassman 2001]. Possibly also during dying DMT plays a role in the (near) death experiences that are sometimes described by the transitioning person. Probably a relation between the transitions from life to death/afterlife and between waking and sleeping exists [McKenna, 1993, Strassman 2001].

Pinolin, 5-meo-DMT and especially DMT are the hormones that may enable us to have these spontaneous, inner experiences. In sleep these are dreams, in wakefulness while practising deep meditation or certain breathing techniques these are visions and out-of-body experiences.

Only a limited amount of knowledge is available about the working mechanisms of the pineal hormones. It is unknown why the different pineal gland hormones have such different effects. As mentioned, tryptophan is converted into the different psychoactive hormones, which are each active in their own way. These all bind to the same membrane protein, the serotonin (or 5-HT) receptor, which is present in many neurons in the entire brain. Through the receptor the hormone induces biochemical processes inside the cell, leading to depolarisation: reversal of negative and positive charge inside and outside the cell. This leads to complex patterns of action potentials, electrical pulses that move from one neuron to the other. The pineal gland hormones possibly don't always stay connected to the receptor in the outer or in the nuclear membrane of the pinealocyte, but sometimes enter the cell and even its nucleus. It has been suggested that pinolin, 5-meo-DMT and DMT can slide in between the base pairs (the genetic code) of DNA, a process called "intercalation". The reason for this idea is that the pineal hormone molecules have a shape and size very similar to the DNA bases. Intercalation changes the spatial shape (conformation) of DNA. This alters its gene expression, the pattern of genes that can and can not be read by the enzymes, which copy the genetic codes in the form of messenger RNA, leading to protein synthesis in the cell [McKenna, 1993].

Coming back to the crystals of magnetite, calcite and hydroxyapatite inside the pinealocytes: science does not know their function yet. Could these crystal be receivers and perhaps senders of still unknown signals of an electromagnetic nature (ELF, radio, light) or a yet unexpected or unknown energy?

Conclusion

The human pineal gland plays a key role in the brain. The gland sends different hormones, all derived from tryptophan, into the blood and cerebrospinal fluid. These influence, through the neurons in the brain, the human state of consciousness. The different pineal hormones function as a kind of keys for the brain cells, inducing different states of consciousness in the course of the day-and-night cycle. In the waking state (serotonin) we are in contact with the outer world. During sleep and during deep meditation (melatonin, and possibly pinolin and (5-meo-)DMT) we are in contact with our inner world. Pinolin and (5-meo-)DMT probably play a role in dreaming and altered states of consciousness, in which experiences of inner, alternative realities and even clairvoyance have been reported. The alternating production of serotonin and melatonin make a sleep-waking rhythm possible.

What we can do to promote a well-functioning pineal gland:
Besides always including sufficient tryptophan-containing food in our meals and besides keeping to a balanced exposure to light and dark, also daily meditation may contribute to a balanced pineal gland. From the many traditions and methods of meditation, each individual may choose which works best for him/her. It also helps to avoid (if possible) next to or in our bed, electrical devices that are powered by the mains.

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