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EC NEUROLOGY
Review Article

The Neural Correlates of the "ID"

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Received: February 26, 2019; **Published:** March 29, 2019

Abstract

Id, ego and superego are three abstract compartments of the human psyche according to the schools of psychoanalysis, established by Freud. Although these are abstract notions, today we have the neuroscientific basis of knowledge for defining them in terms of neuroanatomy and psychopharmacology. Hedonic hot spots or pleasure centers in the limbic system have been identified. Some of them are ventral tegmental are (VTA) cingulate, orbitofrontal cortex, prefrontal cortex (PFC), insula, nucleus accumbens (NA), amygdala, hippocampus and hypothalamus. Actually, there are regions in the brain where the functions of the id arise, mostly in the limbic system. Libido and pleasure principle have the neuroanatomical and neuropharmacological correlates in the brain. During pleasure, passionate love, extreme pleasure, peak experiences, orgasms or prolonged orgasms, these areas are activated; some neurotransmitters such as dopamine, oxytocin, glutamate, GABA, acetylcholine, norepinephrine, endogenous opioids, serotonin and the hormones testosterone and vasopressin mediate the neurotransmission of pleasure and love, which is a peak experience of the id. The reward-pleasure circuitry, which plays important roles in the development of psychological dependence and addiction is also involved in the mechanisms of these functions. Nearly 5000 dopaminergic neurons originating from VTA projecting to NA and PFC control most of the pleasure reactions, which may have great impacts on synaptic plasticity, learning, habituation and influence the components of the human psyche and eventually the personality. Dopaminergic projections of VTA may have as many as 25 x 10^8 synaptic connections at the targets, which can carry 92 gigabytes of "pleasure information". The brain has much more information processing capacity than we can imagine. Dopamine and oxytocin are the major "pleasure, orgasm and happiness" neurotransmitters which the id uses to mediate and perform its discrete functions of the nature, while *"the pleasure principle"* is inevitable, unbeatable and indispensable. When superego counteracts with these functions, psychological disturbances may arise. The centers of ego and superego are probably the cortical and associative areas, particularly frontal, parietal and temporal cortices. This review is a neuroscientific summary of what happens in the brain when the id prevails the superego.

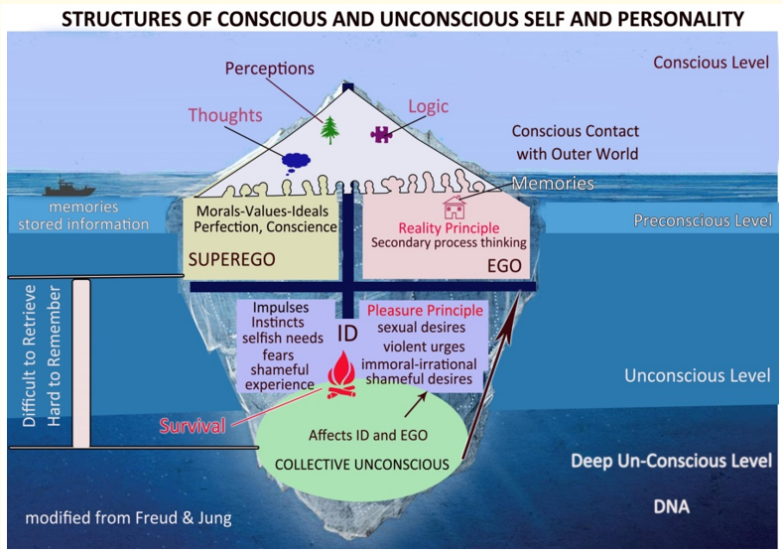
Keywords: *ID; Pleasure Principal; Pleasure-Reward Circuitry; Dopamine; Oxytocin; Ventral Tegmental Area; Nucleus Accumbens; Prefrontal Cortex; Expanded Orgasm; ESR; Hedonic Hot Spot; Pleasure Center*

Introduction

The ID, ego, and super-ego are three distinct, however continuously interacting entities in the inner-psychology (psyche) of human mind defined by Sigmund Freud [1,2]. ID is the instinctive, inherited part of this organization. Ego is the realistic part which plays roles in regulating the desires and cooperates with ID and super-ego. Super-ego is the personality that is created and educated by the norms of the society, family, friends, school and education to harness the instantaneous and incoherent desires of the ID. ID exists by birth and it is the disorganized pieces of the personality, in which person gets signals about basic human needs and instinctual derives, such as sexual needs or other means to survive, from the limbic system. The ID comprises the "libido", which is a function of ID. It acts according

to the psychological innate rule of *"pleasure principal"*. Pleasure is the instinctual driving force that permeates into every detail of human psyche, daily life and it needs instantaneous satisfaction and gratification, whatever the ego, superego or the society say; if, not, some contradictions may arise in the human psychology which lead to neurosis and psychiatric disorders. Human psyche tries to avoid pain or dysphoria and aims to chase the hedonic ways of living; namely, human psychology is built for chasing after *"pleasure"*, which is innate and hereditary [3-7] (Figure 1A).

The real anatomical location of ID was described in the subcortical structures, taken the functions of the ID; such as the limbic system, brain stem, pons, hypothalamus, and partially temporal lobe, olfactory structures, parahippocampal gyrus, orbito-frontal cortex, anterior cingulate cortex; while ego and superego are created by means of the functions of frontal cortex, parietal cortex, partially temporal lobes and occipital cortex [8,9] (Figure 1B) and abstract thinking.



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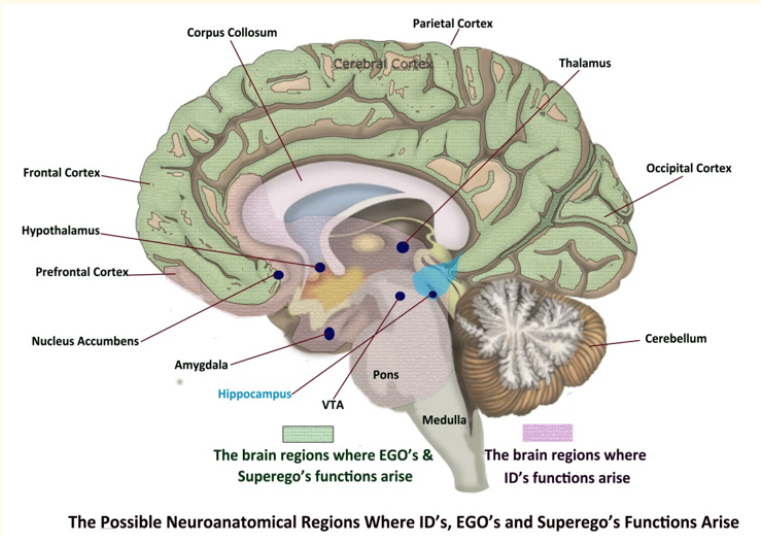

B

Figure 1: *A-The compartments of the personality and psyche as described by Freud and Jung; ID, Ego, Superego, collective unconscious. B-The possible and estimated brain regions where Id's, Ego's and Superego's functions arise.*

Humans are hedonist and pleasure seeking primates [6,10-13]. Pleasure, liking, wanting, enjoying, sexual pleasure and orgasm, are all positive emotions that lead to the general states of mind, *"contentment and happiness"*. Without any of them, life, for humans, would be meaningless. Happiness is a combination of many components. Central nervous system structures are organized and specialized such that there are certain pleasure centers, pleasure-reward circuitry which works using certain modulatory neurotransmitters, such as dopamine, oxytocin, glutamate, GABA, acetylcholine, serotonin, endogenous opioids and norepinephrine.

The ID has some basic neurophysiological and neurochemical ingredients which work in coordination with each other. Similar to the circuitry of reward and pleasure, the circuitries of depression, anxiety, and stress, in which the signaling of some neurotransmitters are enhanced or decreased, have also been defined [9,14-16]. The ID is concealed in the subcortical limbic structures, such as nucleus accumbens (NA), ventral tegmental area (VTA), hypothalamus, amygdala, hippocampus, ventral pallidum, olfactory structures etc. and also the ID has neuroanatomical and neurochemical correlates which work in coordination [8].

Components of pleasure

Pleasure principal uses bio-psychological processes which are inherited and have descended from our grand ancestors, coded in our DNAs. These processes include, making the animals and/or mammals and higher primates become habituated to *"rewards"*. People, all their lives, run, strive, crave and race for various kind of rewards; such as, rewards of "euphoria" and "feeling good"; of good taste and smell; of satisfying their ego; of sexual pleasure and orgasm; of junk food and/or chocolate; of buying as they wish; of possessing; of making money; of getting richer and more powerful.

The animal brain and reward mechanisms in animals are not different, but simpler. It is easier to construct experiments and establish experimental models in animals, since we cannot use invasive techniques in higher primates and humans. Evolution Theory shows us that we have very similar built-in mechanisms and circuits in the brain for a certain mind and neurological states, such as depression, fear, anxiety and pleasure, or even epilepsy and convulsions, to animals. For instance, it was possible to design medication to treat epilepsy, after discovering some of the mechanisms of epileptic discharges and using anti-epileptic agents on animal models of epilepsy, which worked perfectly. Today, most of the epileptic cases can be treated. A drug, such as sodium valproate, vigabatrin (GVG) or benzodiazepines which block electroshock, pentylenetetrazole (PTZ) or kindling seizures in animal models, will also abolish seizures in humans [17]. Most of the anti-depressant or anxiolytic drugs are, also tested, initially in animal models, similarly.

Animals also have some brain areas which activate during pleasure. In both humans and animals there is specific neurotransmitter which mediates pleasure at certain reward centers: dopamine. Even in the insects and bees there are some tiny dopamine neurons, which fire and send action potentials when the bee encounters essence of the flowers for manufacturing honey, a built-in mechanism which is thought to be giving pleasant feelings to the bee [18,19]. Somehow in nature, from insect mind to mammal mind, consciousness has evolved to "perceive dopamine molecule and the activation of dopamine receptors (mostly D1-like) as pleasure and contentment". In the animal brain, the specific pleasure circuits are activated when there is contentment and joy; just like, anxiety, fear, pain, depression circuits perform their opposite functions (Figure 1 and 2) [8,20-23].

A reward activates the reward-pleasure system or hedonic hotspots and generates feelings of pleasure or positive emotions (e.g. liking). At the same time, a reward also activates motivational systems either originating from the limbic system or the anatomical pleasure regions and induces incentive behavior (e.g. wanting). For example, when rats press a key and receive electrical stimulation through an electrode implanted in the lateral hypothalamus, they try to press the key continuously as they can to get more electrical stimulations, which is the well documented "brain stimulation reward (BSR)" [14-16].

The electrical stimulation of some subcortical structures, such as the nucleus accumbens (NA), the lateral hypothalamus, and the ventral tegmental area (VTA), have been proven to induce strong motivational behaviors in animals. It should always be kept in mind that "wanting" and "liking" are two different feelings. "Wanting" is caused by the instinctive approach because of the smell, taste, shape

of the object (such as food); it is a response of the organism towards an incentive salience. In liking there is the "pleasure" factor, and it is a learned behavior, involving short term memory, as well as the dopaminergic and glutamatergic systems (D1-like dopamine and NMDA receptors) (Figure 2) [14,24-27]. For instance, a drug that increases dopamine levels in VTA or NA, such as cocaine or amphetamines, may induce "wanting", because of the stimulation of NA and prefrontal cortex; when dopamine is increased in those regions, there is pleasant feeling both in animals (decrease of anxiety, stress) and in humans (e.g. euphoria, relief, happiness etc). After a while it becomes a learned and sought behavior.

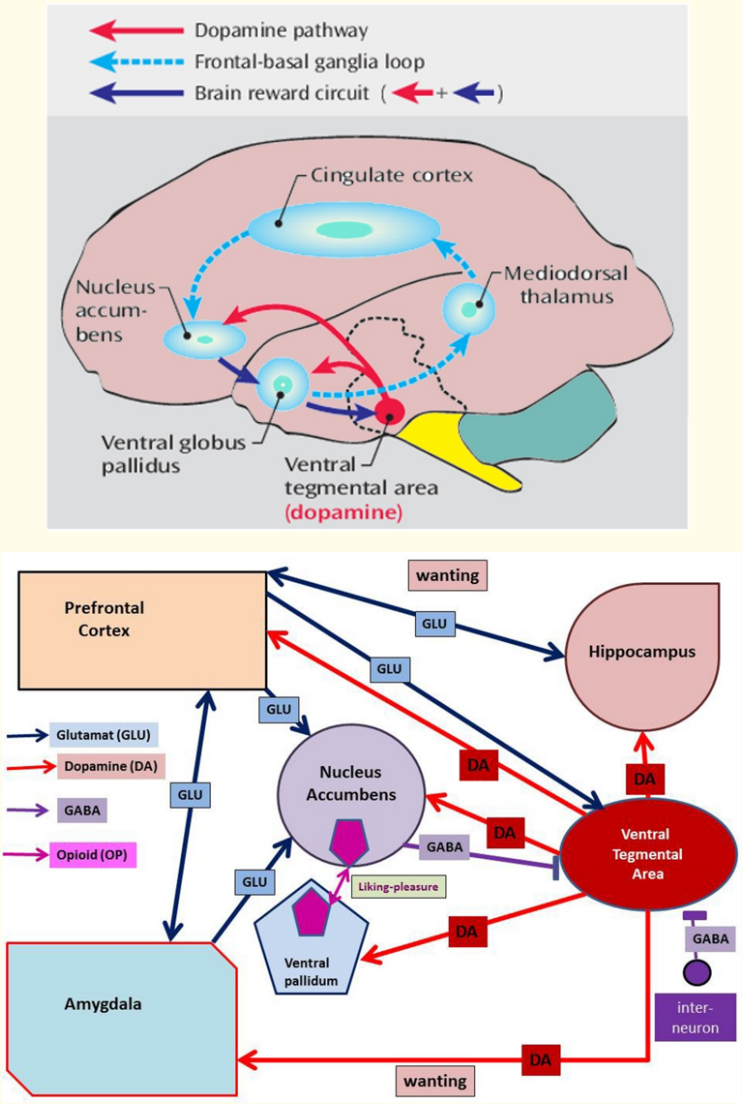

Figure 2: *The known circuitry of pleasure-reward in the limbic system projecting to the cortex and other parts of the brain; also this is the circuitry which plays important roles in love, sexual pleasure, orgasm, seeking behavior, craving, as well as the addiction to drugs, gambling, some habituated behavior, excessive eating and obesity. Glutamate, dopamine, GABA take part in "wanting" behavior; dopamine and endogenous opioids play the major roles in "liking" and pleasure. GABAergic inhibition is also everywhere.*

The stimulation of VTA, NA or lateral hypothalamus have been proposed to induce "wanting". However, the stimulation of orbitofrontal cortex, the medial prefrontal cortex and insula have been proposed to induce a "liking" behavior [16,28] (Figure 3). In "wanting" behavior, there is involvement of glutamate, dopamine and GABA transmission (Figure 4). In "liking and pleasure", there is also involvement of the

endogenous opioids, addition to the stimulation of the dopaminergic system. All these areas have neuronal connections with the other "hedonic hot spots". NA mediates both, "wanting" and "liking" [14,16,25].

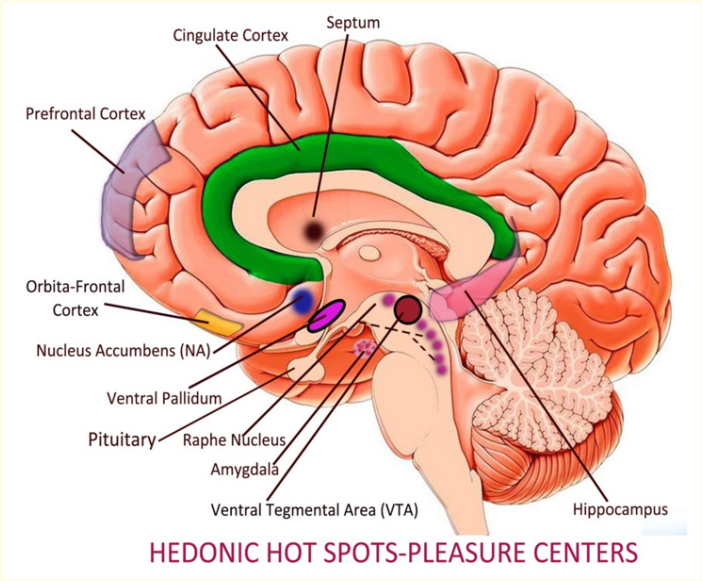

Figure 3: *Hedonic hot spots or pleasure centers of the brain.*

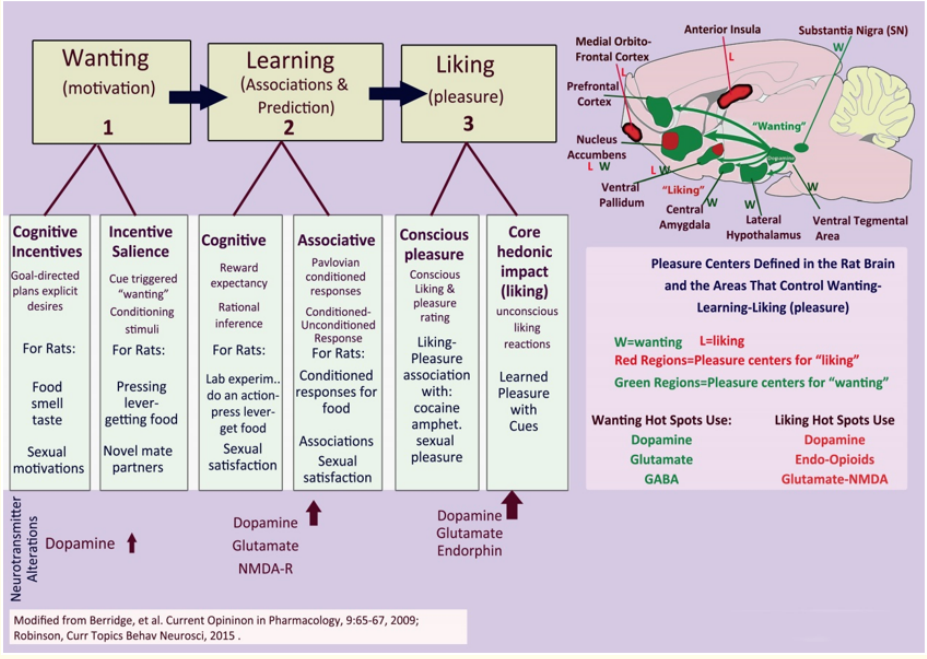

Figure 4: *"Wanting", "learning", "liking" behaviors are three steps which lead to pleasure. Different neurotransmitters and different circuitries take part in the development of each one. The ID is hidden in the biological software of the limbic system.*

The brain areas that are activated with good-positive emotions, pleasure, feelings-emotions, sexual pleasure, and orgasm have been investigated for years. After many supporting findings it was concluded that these areas include:

- Orbitofrontal cortex
- Cingulate cortex
- Medial prefrontal cortex
- Insula
- Nucleus accumbens
- Ventral pallidum
- Substantia nigra
- Ventral tegmental area
- Thalamus and hypothalamus.

These brain areas are often called "hedonic hotspots". The experiments and observations claim that either the electrical (using micro electrodes) or chemical stimulation (amphetamines or cocaine) of these brain structures can induce pleasure or positive emotions; in humans similar regions are also activated during falling in love, making love, orgasm, happiness [15,16,24-31,34,35] (Figures 1-3).

Pleasure neurotransmitter of the ID: Dopamine

Dopamine (DA) is an excitatory or inhibitory neurotransmitter in the central nervous system. DA receptors have subtypes which are mainly two families D1-like (D1, D5) and D2-like (D2, D3, D4) groups. Activation of D1- group receptors increases cyclic adenosine 3, 5,-monophosphate (cAMP) through stimulation of adenylyl cyclase via Gs stimulatory G-proteins. But, activation of D2-group receptors decreases cAMP through Gi (inhibitory) pathway. The other receptor subtypes belong to the D2-like subfamily (D2, D3, and D4) and they are Gi protein-coupled receptors that inhibit adenylyl cyclase and activate K^+ channels [36,37].

Endogenous DA levels and DA release increase in the Ventral Tegmental Area (VTA), Nucleus Accumbens (NA), Orbitofrontal Cortex (ORB-C) and hypothalamus when the CNS stimulant drugs are used such as nicotine, cocaine and methamphetamine [14,16,38]. These stimulant substances are, also, associated with the reward system in those areas by means of increasing the release of DA (or by blocking the re-uptake of DA) into the synaptic cleft extremely, compared to the usual-daily reward system or usual DA concentrations within the synapses.

Most of the animals, perceive dopaminergic transmission at the higher centers of the brain as "pleasure and contentment", an unsolved mystery, which is not understood yet, why? Namely, why in some animals, norepinephrine does not have the similar effects, since norepinephrine works parallel to the actions of DA, also potentializing the DA release? This can be accepted as another proof of the reality of "evolution theory", nature may have chosen to give the role of pleasure to DA, after many trial and errors! The preference of DA by the nature, instead of other modulatory neurotransmission, is a subject of another review.

There are many similarities between the activation of pleasure-reward mechanisms and drug addiction. Reward system of DA in the brain includes the VTA and NA, where a sequence of reactions occurs based on the stimuli of a drug or a behavior. During this cascade of biochemical reactions which occur in milliseconds, short term electrophysiological learning, such as LTP, may develop after the stimulation of D1 and NMDA receptors while pleasure is learned. These drugs stimulate mainly every part of the brain, but particularly VTA, prefrontal cortex and NA as well as some other subcortical structures of the limbic system. Extracellular DA release induces action potential firing at D1 dopaminergic receptors and in some people, they may initiate craving for the drug which is addicted to [39]. In CNS stimulant addicts this craving is correlated with the high concentrations of DA released [40,41]. Craving is an electro-chemical learned behavior hypothesized to be the new adaptation formation of the mesolimbic dopaminergic system [42,43]. The same pleasure-reward system may also mediate the development of psychological addiction to gambling, over-eating and obesity, some certain repeated stereotypic behaviors or habituation (watching TV, internet, pornography or gambling etc.) In animal and human studies self-administration of DA increasing substances, creates some positive-like clinical effects, such as pleasure, euphoria, increased libido, and enhanced sexual pleasure, cessation of anxiety, hedonism, and loss of the depressive mood.

VTA is the dopaminergic transmission center and DA production area, mesocortical dopaminergic pathway starts at VTA with many dopaminergic neurons originating. Nucleus Accumbens (NA) is the center for motivation and goal directed behavior. DA, as a signaling agent in the brain, is very crucial for memory formation; dopaminergic activity and neural transmission helps the animals (or humans) to remember both positive and negative experiences. Traumas probably have a deeper influence in the limbic system and cortex, while positive-hedonic experiences are never forgotten either. This stamped-in memory gives the animals the motivation to repeat the pleasurable experiences (e.g. pressing the lever to deliver electric shocks through an electrode implanted in lateral hypothalamus; or pressing the lever for the reward of cocaine instead of regular food). Dopaminergic, glutamatergic and adrenergic systems work together, while glutamatergic NMDA receptors mediate acute electrophysiological short-term memory, referred as LTP; dopaminergic and adrenergic, as well as acetyl-cholinergic, systems mediate the long-term memory in the limbic structures (e.g. VTA, amygdala and hippocampus) and the neo-cortex (particularly pre-frontal cortex) [24-26,29,33,44,45]. During the course of early development, severe traumas (e.g. epileptic or febrile seizures) can induce long term alterations in the synaptic plasticity, electrophysiology of hippocampus, learning and anxiety, as we have shown recently [10,46,47]. Pleasurable, contentment experiences are also learned very fast and result in the seeking behavior of the reward that had elevated DA-system (e.g. electric shock into the lateral hypothalamus or cocaine for the animals; drug usage, addiction of eating, gambling or habituation in humans).

ID's sexual drive is a built-in component of reproductive behavior which is crucial for the reproduction of human race. Sexual desire and drive are also an important part of the survival instinct. Sexual desire also shapes the emotions, love and sexual satisfaction, making love, orgasm, self-fulfillment and human relations. Since the higher cortical and cognitive processes are very complex in humans, they get much more pleasure than animals in sexual activity and the components of the emotional, psychological and sexual aspects are more complicated. Desire and motivation originate from certain "hedonic hot zones" which are also under the control of balance of some neurotransmitters.

Summary and Conclusion

The ID has very effective ways to express itself, as a built-in bio-software of the human brain; also it has very powerful methods and circuitries to realize its goals, which are embedded in the limbic system. The contradictions of the psyche with the ID (Superego vs ID), may result in the formation of novel synaptic plasticity and new neurochemical balances, which may induce some psychological disorders, such as neurosis, anxiety, depression. Today, actually, we know the neurophysiological basis of what Freud had articulated a century ago, and it was correct! [20].

The ultimate pleasure and peak experience of the ID: Love

The mechanisms of passionate love and what it changes in the brain have not been unraveled until recently. According to Freud and for some researchers, first love develops towards the mother, in some males (Oedipus complex) and in some girls [46,47] it is towards the father (Electra complex) [48]. Structural psychology and psychoanalysis used to concentrate on the childhood experiences and the relationships with the father and mother. Actually, the inherited, built-in reward system in humans, described above, starts to function during the early development and the young brain is very susceptible to traumas, events that give pleasure, subconvulsive discharges, or other phenomena that are perceived as pleasant or unpleasant. Particularly in the development of sexual deviations and parafilias, childhood traumas and/or various hedonic experiences have been proposed to be responsible [48,49].

The term "love" comprises a variety of strong and positive emotional and mental states, where pleasure becomes the topmost. In a passionate love, there is the deepest interpersonal affection, high levels of happiness and pleasure; powerful attachment. Lust and sexual attraction are the most important components, in which one can see the traces of the ID.

Some scientists described love in three stages: lust, attraction, and attachment. Lust is the feeling of strong sexual desire; romantic attraction determines what each individual find attractive and pursue, conserving time and spiritual energy by choosing; and attachment involves staying together for a long time, leaving together, sharing a home, parental duties, mutual defense, and involves feelings of safety and security [50]. Three distinct neural circuitries, including the involvement of various neurotransmitters, and three behavioral patterns, are associated with these three romantic love processes [50,51].

According to the triangular theory of love, there are three components of passionate love [52]: Passion, intimacy and commitment. However, sexual harmony and extreme sexual pleasure should also be added to the classification. In the passionate love, there is enhanced sexual satisfaction and extreme happiness as an outcome of sexual activity (Figure 5).

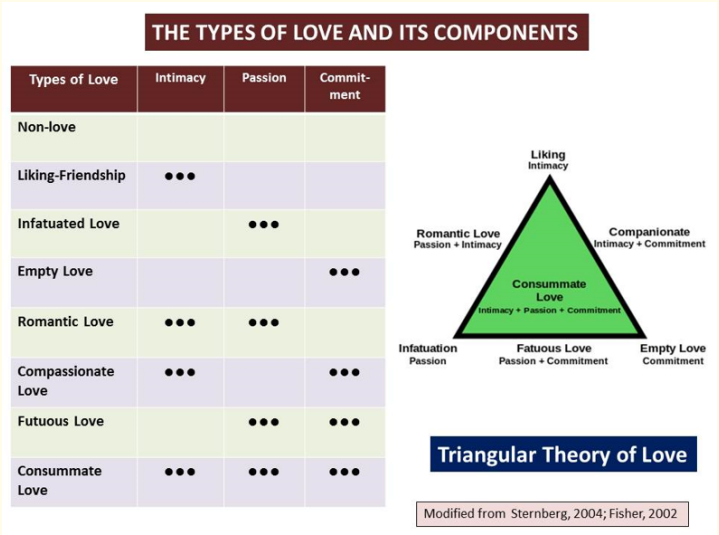

Figure 5: *Types of love and components of love: intimacy, passion and commitment. (Modified from Wikipedia).*

During love, the information emerging from the subconscious and collective unconscious has been proposed to be very crucial. If we analyze the formation of love, we can find many factors emerging from his/her genetic heritage, childhood experiences, subconscious and collective unconscious that compel the person to fall in love. ID is the discreet subordinate of love, most of the time. Many neurochemical, hence behavioral changes happen during a deep and passionate love.

Extensive neuroscience and neuropharmacology research has been accomplished about *"falling in love"* in human subjects [49-64], also using fMRI techniques [20,21,65-77]. Here, we will summarize how brain chemistry is changed during love, as a summary of neurotransmitters, altered during passionate love for men and women (See figure 6 and 7):

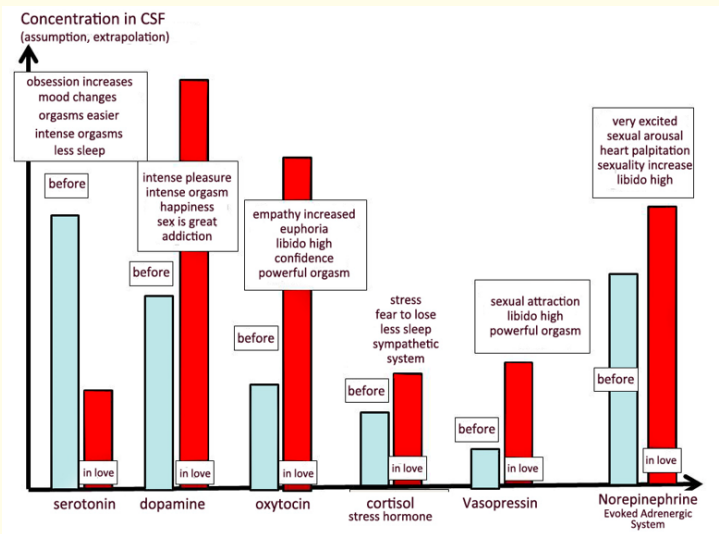

Figure 6: *Neurotransmitter and behavioral changes in the brain during passionate love [1,2,50-66,78].*

Decrease of Serotonin	Increase of Dopamine
• Increased obsession and compulsion • Increased aggression • Mood instability, alterations of mood • Contributes better and intense orgasm in women, particularly. • May induce premature ejaculation in men	• Decreases sadness and unhappy feelings • Increases motivation • Increases joy, happiness, delight • Increases pleasure taken from the love itself • Increases pleasure during making love • Increases the intensity of orgasms particularly in women; very powerful and multiple orgasms • Abolishes anxiety and depression • Increases attachment to the lover • Addiction occurs
Increase of Cortisol (stress hormone)	**Increase of Vasopressin**
• Increases stress • Increases fear to lose • Increases jealousy • Increases attention • Increases susceptibility to painful stimuli • Makes female psychology more fragile, being easily upset and sentimental • Increases attachment	• Increases sexual arousal • Increases sexual attraction • Increases libido • Decreases anxiety
Increase of Oxytocin	**Increase of Norepinephrine**
• Increases euphoria • Increases motivation • Increases confidence • Attachment to the lover is increased • Increases happiness. A very happy mood • Increases libido • Increases pleasure taken from love making • Induces more intense and powerful orgasms • Increases empathy • Increases being romantic and sentimental • Decreases fear and anxiety • Increases attachment to life	• Sympathetic Autonomous Nervous System is activated • Increases excitation. • Increases heart beats and palpitations • Episodes of hypertension • Increases alertness • Increases pleasure • Increases libido • Increases joyful mood and happiness • May increase anxiety • Decreases sleep

Figure 7: *Alterations of Behavior in Response to Neurotransmitter Changes During Love [20,50,66,74-76,78-80].*

- Serotonin decreases very much compared to normal (that of before falling in love).
- Dopamine increases a lot compared to normal.
- Oxytocin increases a lot compared to normal.
- Stress hormone cortisol increases slightly.
- Norepinephrine is increased slightly; adrenergic sympathetic autonomous system is activated.
- Vasopressin is increased.
- Testosterone increases both in men and women; hence libido and sexual pleasure is increased.

In the case of love, being with or making love with the loved one becomes a super-reward and it is strived for compulsively after a while. Without any sexual activity, even being together with the lover is always sought; that person becomes the most important individual in her/his life.

Love, in human beings, is a complex behavioral, emotional and consciousness state and a *"peak experience"*; it requires many higher cortical functions in coordination with many alterations in the limbic circuitry, where the ID is located. Brain chemistry changes, for at least 6 months; in some cases these changes may continue up to two years or more. Generally, the changes determined in the blood and cerebrospinal fluid (CSF) return to normal in six months [10,11,56-70,20,78]. The components emerging from the genetic factors, subconscious, collective unconsciousness, limbic system, learned information and conditioning since childhood, sexual preferences, fanta-

sies, childhood traumas, abstract thinking, cognitive factors of the individual, social norms and conditioning, social and religious dogmas, biases, etc., contribute to the development of love [10,20].

What kind of behavioral changes occur when the ID takes the steer?

Love can be accepted as a kind of compulsion, however with positive emotions; rewarding and inducing happiness. Changes in the brain chemistry are reflected to the psychology, behavior, mood, motivation, desires, libido, pleasure and contentment of the individual lovers. During love, sexual pleasure and orgasms are enhanced, particularly in women. Better and more intense the orgasms are, the more oxytocin is released; hence, love strengthens, and more attachment occurs. Oxytocin, which is secreted from hypothalamic paraventricular nucleus and posterior pituitary, is a hormone in the bloodstream and a neurotransmitter in the brain. Acute oxytocin release induces various behavioral changes; it is the specific neurotransmitter of love, sexual pleasure, orgasm, bonding, empathy, attachment, and motherhood [10,11,20,21,33,68-78] (Figure 7).

Neuro-imaging studies of passionate love

Parieto-temporo-occipital region induces the perception of integrity of the self with the environment. Activation of this region makes the person to differentiate self from the outer world and space. During love this region is inactivated [53,56,58,69]; hence the individuals may perceive a diminishing ego, or an ego-loss, which is replaced by a perception of integration and unification (with the partner, with the nature or universe) feeling [53,56,58]. Similar feelings and mood may be experienced in some mystical phenomena [75,79] and during the influence of psychoactive substances [69,74,75].

Aron., *et al.* (2005) [80] also focused on early stage passionate love, and found that when participants looked at the face of their partner and thought about pleasurable, non-sexual events involving the partner, activation was detected in the right caudate nucleus and the ventral tegmental area (VTA), whereas the amygdala, which mediates aggression, showed deactivation. Caudate nucleus and VTA are the most consistent regions associated with romantic love in terms of activation [53,69,80,81], coherent with the fact that these dopamine-rich regions are strongly associated with reward and goal-directed behavior, supporting the notion that romantic love is an intense motivational state and extraordinary experience which also uses the reward-pleasure circuitry and some of the "hedonic hot spots" (See Figure-8).

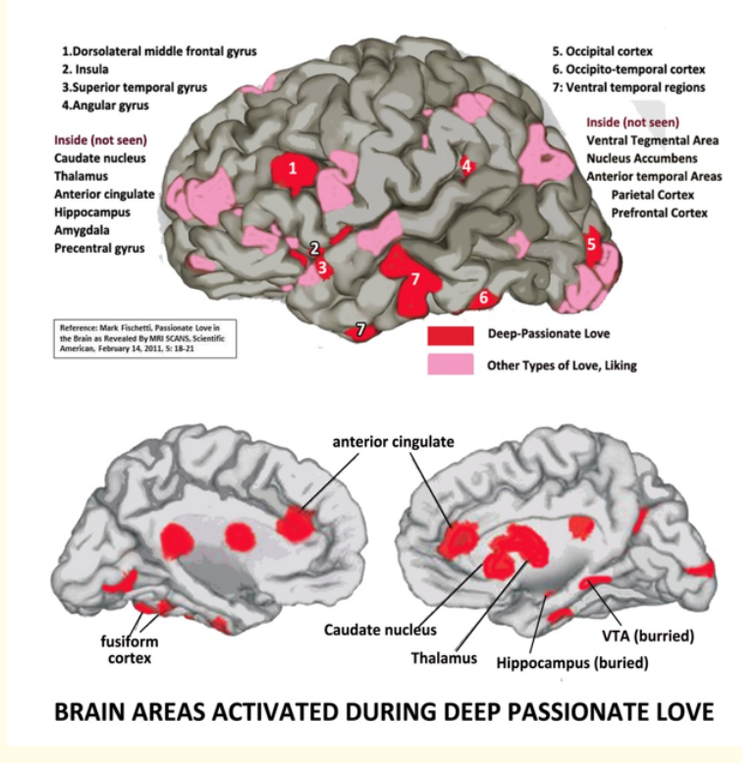

Figure 8: *Alterations of Behavior in Response to Neurotransmitter Changes During Love [20,50,66,74-76,78-80].*

Informatics and biophysics of neurons, dopamine and pleasure

Human brain and human psyche have a very complicated structure. There are 10^{13} neurons in the human brain. The duration of an action potential is 0.8 millisecond, however most neurons can fire an action potential in every 0. 5 milliseconds. If we assume that one bit of information in the brain contains "YES" and "NO" binary algebra (0 or 1, in binary mathematics), and one bit of information corresponds to 2 action potentials from a neuron; it is estimated that one synapse can store 4.7 bits of information [20]. So, 4.7 bits of information in one synapse can be stored in 1 millisecond. Each neuron can make from a couple to 10^4 synapses; let's assume that as an average one neuron makes 10^3 synapses with other neurons. Then, through the synapses of the human brain, 10^3 x 10^{13} x 4.7 bits of information can be stored in one millisecond, namely 4.7 x 10^{16} bits of information. The byte is a unit of digital information technology that most commonly consists of eight bits, representing a binary number. In one millisecond ((4.7 x 10^{16})/8) bytes of information, in computer terms, can pass and be stored in the human brain. In modern computer technology, the computer systems started use 32 or 64 bit systems; so, to compare with our current modern computers (and current byte concept), it is better to take one byte as 64 bits, then in one millisecond (4.7 x 10^{16})/64 bytes can be processed in one millisecond; which is 0.0754 x 10^{16} bytes; or 754 x 10^{12} bytes. 754 terabytes of information can be passed in one millisecond through whole brain synapses (among 10^{16} synapses, approximately). In one second, while you blink your eye, 754 terabytes x 1000, or 754 peta bytes of information can be processed in the brain. In a day, during a wakeful period of 16 hours (which is 3600 x 16 = 576 x 10^2 seconds) is 576 x 10^2 seconds. During, one day when you are conscious 576 x 10^2 x 754 petabytes of information is processed. Approximately this makes, (576 x 754 x 10^2= 434 304 x 10^2) approximately, 4 x 10^5 x 10^2, namely (4 x 10^7) petabytes of information, or 40,000 EXA bytes of information or 40 ZETTA bytes of information. For comparison, the 19 million volumes in the US Library of Congress represent about 10 terabytes of data. In one single day, the human brain has the capacity of processing the data much more than the total volumes of US Library of Congress. However, it does not work that way because of various reasons, particularly because of many inhibitory synaptic connections, so many action potentials would be blocked and inhibited at certain levels (inhibitory serotonin, enkephalin, endorphin, GABA, dopamine-D2-like receptors etc.); second the brain would not be able fire continuously at every neuron and at every synapse, at every millisecond; otherwise there would be chaos and it would become epileptic. Third, the brain cannot store this much information in the form of proteins, RNA or DNA, otherwise we would have to carry a brain as big as an elephant; only one way, possible to store this much information is: to record it in holograms! There is a hypothesis about the *"holographic brain"* proposed by some researchers [82-88]. It is not yet proven though the brain keeps the information holographical!

Karl Pribram's "holonomic brain theory" weaves several concepts together in forming the theory [82-86,89]. A partial list is the following (http://www.acsa2000.net/bcngroup/jponkp/):

1. The apparent spectral frequency filtering aspect of cortical cells.
2. The relationship between Fourier transforms and holograms.
3. The fact that selective brain damage doesn't necessarily erase specific memories.
4. The computational advantage to performing correlations in the spectral domain.
5. The specific abilities of the brains of some people that can exceed the known possible limits. For instance, some autistic or genius people can multiply five digit numbers instantaneously, faster than calculators, (e.g. the synesthetic genius Daniel Tammet who sees the numbers in shapes and colors and his multiplications' pictures are like landscape paintings. Tammet can multiple numbers using his synesthetic abilities faster than computers. Tammet went to Iceland and learned Icelandic in 7 days and made an interview in Iceland TV speaking Icelandic. There are numerous genius mathematicians like him, how can neuroscience explain these extraordinary abilities?).
6. His idea of conscious experience being concurrent with the brain performing these Fourier-like transformations (which simultaneously correlate a perception with other previously stored perceptions). He believes that conscious experience is the act of correlation itself and this correlation occurs in the dendritic structures by the summation of the polarizations (and depolarizations) through the processes in the dendritic networks.
7. The brain is a «dissipative structure» and self-organizes around a least-action principle of minimizing a certain uncertainty relation.

Even though, information –somehow- is stored in the brain in holograms, so much information normally does not, of course, flow through the brain! Huge amount of data and information everyday fills the human brain though! Above calculations are made just to give an idea of the capacity of the biological computer of *H. sapiens*. The consciousness is aware only of a very small proportion of the information mentioned, namely all the processed information in the brain is not reflected to the conscious mind.

This huge volume of information does not directly pass into our conscious levels (See figure 1A), however, it is filtered through the mind; the consciousness does not perceive and process this amount of information. There is also a phenomenon which is coined as subthreshold perception and subliminal perception. It is hypothesized by Nick Herbert [90] that through the 5 senses 10^8 bits of information enters into the brain as perception in each second and 10^4 bits of information is processed as an output every second; Herbert, claims that the information that unconsciously enters our brain is nearly 10^{13} bits every second, but most of it filtered and silenced (See figure 9). The consciousness is not aware of this much information, the filtering system of the perceiving mind choses the useful information only, drops the rest into thrash. According to Herbert, average person's "ordinary conscious mind" can process nearly 50 bits of information every second [90]. Besides this is the input from the outer world, there is also a fair amount of stimuli and information coming from the inside of the brain from the subconscious and collective unconscious layers of mind, which compromise the configuration of various forms of feelings, emotions, states of mind and mood (See figure 1A and figure 9).

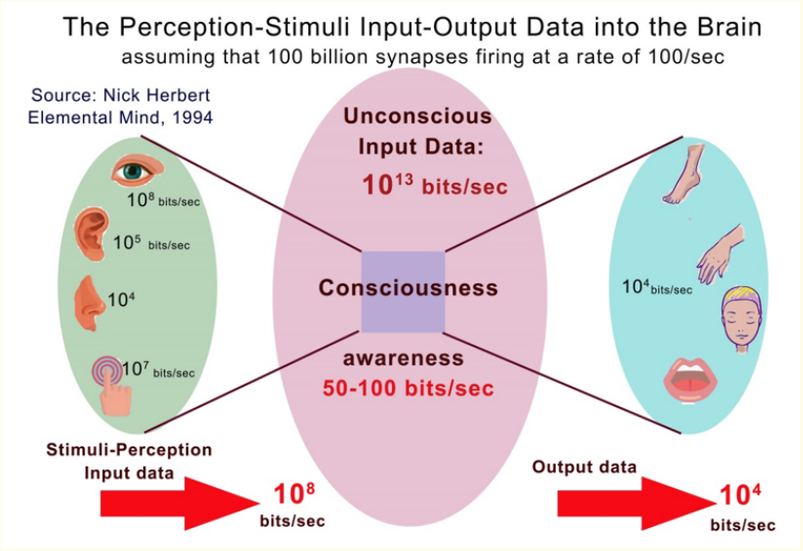

Figure 9: *The sizes of input and output data entering into the brain via five senses and internal organs. The conscious processed data is estimated to be 50 - 100 bits/sec; while there is huge amount of subliminal and unconscious data which is not either processed or kept without awareness [90].*

For instance, the neocortical dopaminergic system which includes the VTA extends its fibers into the caudate nucleus and prefrontal, cingulate and perirhinal cortices; which are generally referred as meso-cortico-limbic system. In the human brain, there are relatively few dopaminergic neurons in the SNpc (substantia nigra, pars compacta) and VTA (less than 400,000 in the SNpc and roughly 5,000 in the VTA) [91,92]. Despite the fact that the number of VTA neurons is not that a great number, the projections from individual neurons are very extensive and hence modulate various brain functions, including pleasure, emotions and mood. The midbrain dopaminergic neuron is estimated to have total axonal (including collaterals) length of 74 cm [91] whereas synaptic connections are very extensive. One dopaminergic neuron in the VTA can extend to 500,000 terminals or synapses common for an individual neuron [91]. Most of the pleasure responses are generated by those 5000 dopaminergic neurons and nearly 25 x 10^8 dopamine releasing synapses. A dopaminergic neuron can fire 500 action potentials in one second, let' say, in one second ((4.7 bits x 25 x 10^8 x 500)/64) bytes of dopaminergic pleasure information can be processed originating from VTA. This is 918 x 10^8 bytes, or nearly 92 gigabytes. So, 92 GB of dopaminergic pleasure information can be processed. Of course this is not actually pleasure, but our consciousness perceives such a dopaminergic discharge as pleasure, which is an illusion of the conscious mind, predetermined in the bio-software of the ID.

Such a complex nervous system, with nearly infinite number of connections and infinite number of the configurations of neural networks and infinite quanta of neurotransmitters, should have been organized to work properly and coherently towards one or two goals or aims, such as survival and/or *"pleasure principal"*. All the mood states, such as, joyfulness, ecstasy, happiness, euphoria, pleasure, orgasm, craving, addiction and other feelings, mood states, good or bad mental states can be reclassified into graded subsets (or subunits), while each subgroup or subunit has neuronal network information value, in megabytes or gigabytes (allowing us to compare with modern computers). Today, it is difficult to visualize this kind of an informatics system; however, with the aid of future computers it will be possible to figure out the biophysics and informatics of neural networks and neurotransmitters which leads to complex features of the psyche, such as pleasure, which is one of the topmost driving forces of life, hidden as a discreet bio-software of the ID.

Conclusion

During the last half century, neuroscience has proven that all mind and mood states, feelings, emotions, thought, abstract thinking, psychological and mental disorders have 1-neuroanatomical 2-neurochemical 3-neuro physiological or pathophysiological basis and mechanisms of occurrence. Some accepted classifications in psychiatry, described long ago, such as ID, ego, superego, *do* also have neurochemical basis and mechanisms which can be influenced and/or altered by the modern methods of psychopharmacology and/or biological psychiatry. Any abstractions about human psyche which do not depend on pure neuroscience and neuropharmacology are not valid anymore, including the spirits, souls, and other heavenly creatures which take their origins from early pagan beliefs or institutionalized religions [94,95]. In a century, imaging techniques, non-invasive neuropharmacology techniques will evolve and develop. By then, many perplexing issues in human psychology will be unraveled by means of the methods of neuroscience.

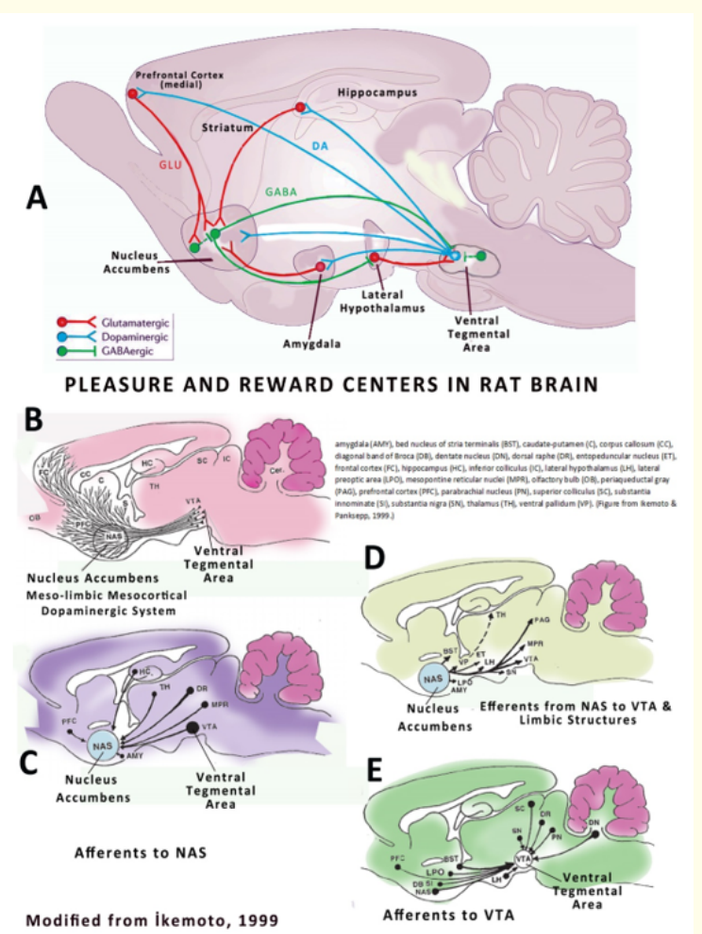

Figure 10: *A- Pleasure-Reward Seeking Behavior inducing regions in the rat brain. B- Ascending projections from the midbrain ventral tegmental area (VTA) dopamine neurons that innervate the nucleus accumbens (NAS) and prefrontal cortex (PFC) among other regions. C- The major afferent projections to the NAS D- Efferents (descending) of the nucleus accumbens, mostly GABAergic. E- Afferent projections to the VTA. Other abbreviations: amygdala (AMY), bed nucleus of stria terminalis (BST), caudate-putamen (C), corpus callosum (CC), diagonal band of Broca (DB), dentate nucleus (DN), dorsal raphe (DR), entopeduncular nucleus (ET), frontal cortex (FC), hippocampus (HC), inferior colliculus (IC), lateral hypothalamus (LH), lateral preoptic area (LPO), mesopontine reticular nuclei (MPR), olfactory bulb (OB), periaqueductal gray (PAG), prefrontal cortex (PFC), parabrachial nucleus (PN), superior colliculus (SC), substantia innominate (SI), substantia nigra (SN), thalamus (TH), ventral pallidum (VP) [93].*

Acknowledgements

This review is supported by the funds of BAP and Istanbul University. The figures are drawn originally or modified by Dr. Ümit Sayın. Similar reviews on the topic are published at the SexuS Journal (www.sexusjournal.com).

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