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Rational Thought, Cognition and Knowledge

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Abstract

An exposition on how the brain works as theoretical application of the grand unified theory (GUT), this paper applies the new methodology of qualitative mathematics and modeling to trace the signals from the external world through the sense organs where they are encoded on brain waves and transmitted through the nerves to a primitive nodal region in the creative-integrative region (CIR) of the cortex. They form a tree of activated (vibrated) neural chains via resonance that triggers sensation and models a concept (cognition) there even after the signals from an event has stopped coming. The concept is defined by the vibration characteristics of the tree and its components. When thought leaves its focus on it, the tree reverts back to its normal vibration and transfers its components to their respective sensation regions for storage as memory in due course. Then the paper discusses recollection of concepts for use in thought and construction of knowledge and its application to wellness.

Keywords: brain wave, cognition, convertor, creative-integrative region, creativity, superstring

Abbreviations: GUT – Grand Unified Theory, QMAM – Qualitative Mathematics and Modeling, CIR – Creative-Integrative Region, UTE – The Unified Theory of Evolution

1. Introduction

As theoretical application of GUT (Escultura, 2008) that unifies the natural sciences (Escultura, 2013a & 2014a) and the Unified Theory of Evolution (Escultura, 2010a, 2015a, & 2015b), the paper adopts the standards and style of physics and precision of its language – mathematics – especially, with respect to research procedures and requirements. It explains how the brain works and the physical processes in the cortex simultaneous with mental activity. It is important for research on intelligence and artificial intelligence and analysis of dreams. Its practical contribution to wellness is discussed in (Escultura, 2012a, 2015a, 2015b, & in press). The focus is the *science* of the subject and the evidence and verification drawn from known results and cited references. The strategy is to identify the laws of nature taken from GUT and the laws of thought, as basic premises or hypotheses, upon which the theory of intelligence as articulation of scientific knowledge in this field is built that explains rational thought, cognition and knowledge.

2. Method

This paper would have been impossible with the use of the traditional methodology of quantitative modeling (formerly called mathematical modeling) *alone* that *describes* the appearances of nature (natural phenomena) its tools computation and measurement. Therefore, the crucial factor in the paper is the new methodology, qualitative mathematics and modelling (QMAM), introduced in and the main contribution of (Escultura, 1970) that *explains* the appearances of nature and how it works by natural laws, its tool qualitative mathematics, the complement of computation and measurement and qualitative model of rational thought (Escultura, 2013a & 2014a). It is an advance over (Escultura, 2012b & 2014b). QMAM shifts the subject matter of science from the appearances of nature to nature itself and traditional science to the new science articulated by GUT (Escultura, 2013a & 2014a). It is particularly suited for complex systems (Escultura, 2011a) which are not amenable to computation and measurement. Qualitative mathematics includes the following activity,

Making conclusions, *visualizing*, *abstracting*, *thought experimenting*, *learning*, *creating abstract and physical concepts (the former created by thought, the latter has referent)*, *intuition*, *imagination*, *trial and error to sift out what is valid*, *negating what is known to gain insights into the unknown*, *altering premises or axioms to draw out new conclusions*, *thinking backwards*, *finding basic premises for a mathematical space and devising techniques that yield results.*

3. The Grand Unified Theory

Since this paper and UTE are theoretical applications of GUT we present its summary.

3.1. Basic Concepts and Some Laws

Dark matter is one of the two fundamental states of matter consisting of non-agitated superstrings, the *superstring* being the fundamental building block of matter, ordinary or visible matter the other fundamental state. Proof and derivation of its structure and properties is recounted in (Escultura, 2013a). Clean, free and inexhaustible, dark matter is abundant everywhere in the cosmos and accounts for over 95% of our universe (Escultura, 2009a). However, non-agitated superstring is not presently observable owing to its tiny size and is known only by its impact on visible matter. *Energy* is motion of mater and the two are never separate; therefore, neither pure matter nor pure energy exists. *Wave* is suitably synchronized vibration of the medium (Escultura, 2013a). Electromagnetic wave is generated by the normal vibration of atomic nucleus and propagated across dark matter. The nuclear normal vibration is due to the impact of cosmic waves coming from all directions its vibration characteristics principally determined by the structure of the nucleus in accordance with the following natural law inspired by Engel's Dialectics of Nature (Haldane, 1939):

Internal-External Factor Dichotomy Law. *The interaction, dynamics and physical characteristics of a physical system is shaped by internal and external factors, in general, the internal is principal over the external and the latter works through the former.*

The next natural law was discovered in the course of analyzing the disastrous final flight of the Columbia space shuttle (Escultura, 2007 & 2013c).

Resonance Law. *Resonance between waves or vibrations occurs when they have same characteristics including wavelength and configuration. The degree of resonance rises as the difference between wave characteristics and decreases as the difference between orders of magnitude of their wavelengths (or frequencies), the latter principal.*

Waves of same order of magnitude but encoded with different wave characteristics superpose their characteristics on each other and form composite waves (Escultura, 2012a, 2015a, & in press).

The next natural law is the fundamental natural law, an enrichment and extension of First Law of Thermodynamics to dark matter; all other natural laws are consistent with it.

Energy Conservation Law. *In any physical system and its interaction*, *the sum of kinetic* (*visible*) *and latent* (*dark*) *energy is constant*, *gain of energy is maximal and loss of energy is minimal*.

The next natural law states various expressions or forms of Energy Conservation.

Energy Conservation Equivalence Law. *Energy conservation has many expressions or forms: order, symmetry, economy, least action, optimality efficiency, stability, self-similarity (nested fractal), coherence, resonance, quantization, synchronization, smoothness, uniformity, motion-symmetry balance, non-redundancy, non-extravagance, evolution to infinitesimal configuration, helical and related configuration, e.g., circular, spiral and sinusoidal, and, in biology, genetic encoding of physical characteristics, reproduction, order in diversity and complexity of functions and configuration that provides optimal capability.*

Each component is a physical principle. The next two natural laws are central to flux interaction (Escultura, 2001, 2010b, & 2013b).

Flux-Low-Pressure Complementarity. Low pressure sucks matter around it and the initial rush of matter towards region of low pressure stabilizes into local turbulence, e.g., hurricane; conversely, coherent flux induces low pressure around it.

Flux Compatibility*. *Two fluxes of same direction attract, of opposite directions repel.*

3.2. The Superstring

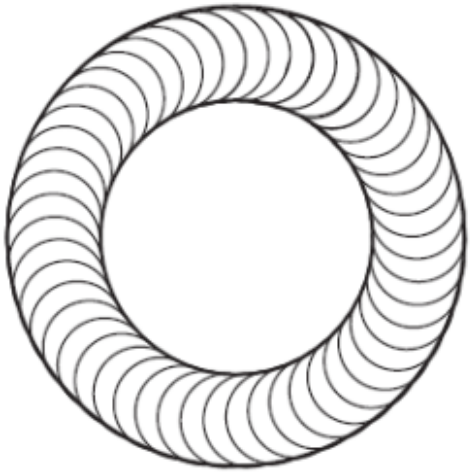

Figure 1. An artist's conception of a semi-agitated superstring. A non-agitated superstring, its toroidal flux, has a similar nested fractal structure as itself and travels through its helical cycles at the speed of 7x1022 cm/sec. The helix winds around the torus rapidly its cycles infinitesimally close (Escultura, 2011b).

Hit by suitable electromagnetic wave non-agitated superstring (a) is thrown by impact, bounces with others and becomes non-agitated superstring when imparted energy is dissipated or (b) is sucked by its path and forms a loop, the original superstring called toroidal flux traveling through the loop at $7(10^{22})$ cm/sec (Atsukovsky, 1990). Its path shrinks to energy-conserving form: circular helical loop like a lady's spring bracelet (Fig. 1). By Energy Conservation and Energy Conservation Equivalence) its toroidal flux travels through its cycles at this speed. By fractal principle its toroidal flux, a superstring, travels at this speed, etc., forming fractal sequence of toroidal fluxes, each a superstring, *without a last element*. The superstring is identified with the first term of its fractal sequence since its interactions are determined by it. Its discovery (Escultura, 2013a) is based on (Watson, 1998; Glanz, 1998) and summarized by the next natural law.

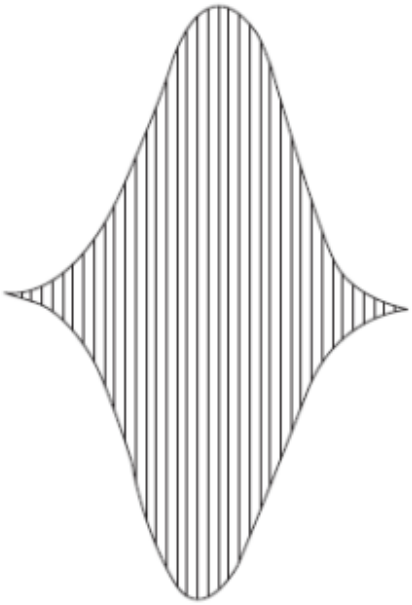

Figure 2. A simple primum bulged segment of semi-agitated superstring and a magnet with induced vortex flux hidden. Its polarity conforms to the right-hand rule of electromagnetism: when the index finger points to the direction of its toroidal flux, the thumb points to the N-pole (Escultura, 2011b).

Existence of the Fundamental Building Block Of Matter and Its Generalized Nested Fractal Structure. *The basic constituent of dark matter is the non-agitated superstring, a circular helical loop and nested fractal sequence of superstrings or toroidal fluxes, with itself as first term; each toroidal flux in the sequence is a superstring having toroidal flux, a superstring, traveling at 7(10^{22}) cm/sec through its cycles, etc.; each superstring except the first, is contained in and self-similar to the preceding term in structure, behavior and properties.*

Figure 3. The proton two +quarks joined by a -quark at their vortex fluxes' rims by flux compatibility (left). The neutron consisting of a pronton, electron and neutrino (right); the neutrino is represented by a figure 8 since it is a coupled primum of opposite but numerically equal charge joined likewise at their fluxes' rims (Escultura, 2011b).

This structure called nested generalized physical fractal (Escultura, 2011c; Edgar, 1990) makes the superstring indestructible and the Universe of dark matter timeless, i.e. no beginning and no end, and boundless, by Flux-Low-Pressure Complementarity; our universe is a finite local bubble in it among other local universes (Hellemans, 1999; Scientific American, 1995). The superstring is non-agitated if its cycle length (CL) < 10^{-16} m, semi-agitated if 10^{-16} < CL < 10^{-14} m, agitated if a segment has CL > 10^{-14} m in which case it is a primum, unit of visible matter. Hit by suitable electromagnetic wave, (c) the first term of non-agitated superstring expands to semi-agitated. When

semi-agitated superstring is hit by suitable cosmic wave a pair of mutually exclusive events occurs: (d) the first term of its fractal superstring bulges and becomes a primum (Fig. 2), its toroidal flux non-agitated, or (e) the first term breaks its toroidal flux remaining dark. The basic prima are the electron, +quark and –quark, charges, 2/3 and −1/3, respectively (Gerlovin, 1990); basic because they comprise of the atom. The other stable simple primum is the positron, charge +1, anti-matter of the electron. The stable coupled prima are the proton, neutron and neutrino, charges +1, 0 and 0, respectively. The derivation of the primal structure and properties are in (Escultura, 2013a) (the proton, neutron and nucleus of light isotope are illustrated in Fig. 3(a), Fig. 3(b) and Fig. 4. Agitated or non-agitated the superstring is nested generalized physical fractal; its huge latent energy comes from its toroidal fluxes. We summarize our findings.

Dark-to-Visible-Matter Conversion Law. *When suitable electromagnetic wave hits a semi-agitated superstring one of these occurs: (a) the outer superstring breaks, its toroidal flux remaining non-agitated (dark); (b) a segment bulges to a primum, agitated superstring and unit of visible matter.*

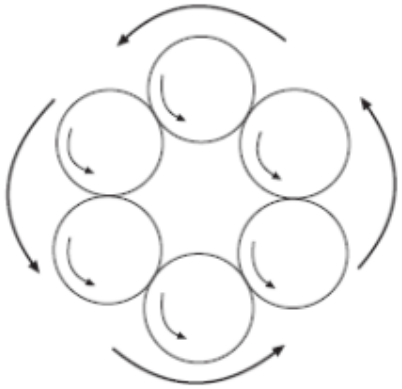

Figure 4. Light nucleus viewed from the north-pole. The -quarks that join the protons are not shown as the -quark is 1/400 as massive as the proton. In reality the protons are joined by the -quarks at the rims of their vortex fluxes, by energy conservation. The neutrons are not indicated as they do not contribute to the vortex flux of the atom; moreover, they are neutral (no net vortex fluxes around them) (Escultura, 2011b).

Electromagnetic wave is hugely energetic being generated by the vibration of the fractal atomic nucleus. It triggers thought (Escultura, 2012b), converts dark to visible matter and is the medium of all motions in the Cosmos (Escultura, 2013a). Like primum, a photon (primum that has broken off its loop (Escultura, 2009a) rides on electromagnetic wave (Fig. 5). Thus, electromagnetic wave is the *prime mover* of our universe.

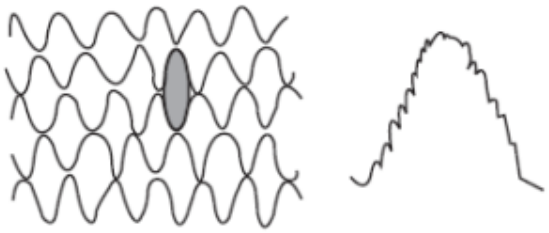

Figure 5. A segment of a beam of basic cosmic waves of the same order of magnitude; a primum or photon in flight (shaded) is lodged between two basic cosmic waves of opposite crests with wave length of the same order of magnitude as its envelope (left). An arc of a basic cosmic wave showing the first two terms of its nested fractal sequence (right) (Escultura, 2011b).

A recent milestone in biology was the discovery that brain waves are the common medium of the brain and the gene for their functions (Escultura, 2012a, 2015a, 2015b, & in press). This follows from the findings in (Osipenko, Pokrovsky, Krylov, & Plakhova, 1999; Krylov & Shehegelov, 1999) that pain sensation produces molecules in the neural membrane and the principles of uniformity, non-redundancy and non-extravagance.

Brain wave is electromagnetic wave encoded with the vibration characteristics of the genes in the cell. The primary function of the brain is control-coordination of body processes and functions, its secondary function thought. The primary function of the gene is the manufacture of the tissues of living things in the cellular membranes just as the genes in the mitochondria are responsible for the manufacture in its pair of cellular membranes the substances that sustain the cell and its functions and charged prima that provide the energy for carrying out its functions. The secondary function of the genes in the chromosomes is passing on the genetic code to the offspring in reproduction.

4. The Theory of Intelligence

Intelligence is the capability of thought for mental activity including creativity and learning.

4.1. The Human Brain

The human brain packs 100 billion neurons (nerve cells), aside from the more numerous glial cells that amplify neural signals, comprising jelly-like grey and white matter that form branching network of thread-like tendrils called dendrites and axons sticking out of the neuron and connecting to other neurons. Two neurons are joined by two dendrites (one from each) connected by a synapse at their tips. The axon consists of bundles of neural chains; their dendrites branch out at its tips into contact points through synapses that join with the dendrite tips of neural bundles in adjoining axon. Together with physiological regulators, e.g., *serotonin*, they comprise the brain, the command center of all body processes and motion, its principal function. The CIR stretches from under the forehead through the top of the upper lobe of the brain. It is the command center of mental and conscious body activities. Around it on the left, back and right of the upper lobe are the sensation regions just above the ears. They store concepts' components as memory. Together with the CIR, they form the cortex, the region of thought that accounts for less than 2% of the brain's mass. The cortex is 1/4 inch thick and convoluted that yields surface area of 16 square ft.

The individual dendrites serve as communication links between separate neural sequences that sustains general consciousness. The neural sequences serve as passage ways of signals from the sense organs to the CIR. The CIR extends its control through the huge mass of neurons that lie under the cortex through the spinal column and the network of nerves that reaches the extremities and remotest parts of the body. The spinal column is the command center of all automatic motion and processes in the human body including reflexes but the CIR monitors and interprets and makes direct intervention in response if needed. The sense organs are the CIR's receptor of signals from the real world external to them (Escultura, 2012b). We state the first natural law of thought.

1* *The CIR has sufficient neural chains that resonate with brain waves encoded with signals and their vibration characteristics coming from the various sense organs.*

This axiom makes thought possible. Under normal conditions, signals from the sense organs go through and are not blocked off anywhere in the cortex. Departure from the norm such as color blindness is genetic. Therefore, it is amenable to electromagnetic treatment through genetic modification and alteration (Escultura, 2012a, 2015a, 2015b, & in press).

As signals jump from one dendrite tip to another belonging to an adjoining neuron of the neural chains in the CIR, it sparks like a radio transmitter does and sends out brain waves in all directions across dark matter.

The brain is the most active organ of the body utilizing disproportionately much energy from the food the body takes – 25% – compared to the ratio of its weight to body weight which is less than 2%. Most of it is used for mental activity and control of body functions (Escultura, 2012b, 2014b, & 2015b). This is the reason research and development to generate high technology, now GUT technology which is powered by clean, free, inexhaustible dark matter that is abundant everywhere in the cosmos (Escultura, 2011a), requires huge budgetary allocation.

Human intelligence has little to do with the size of the brain. While size provides more space for specialized functions there are caveats: (a) larger brain means longer neural chains between nodal regions of specialized sections of the cortex areas that slows down the brain's functions and correspondence between brain regions and neurons since neural dendrite connections are the avenues for internal communication within the cortex for information, intuition and assessment, (b) it raises energy consumption, dissipation of heat and the sheer time it takes for neural impulses to travel from one part of the brain to another (c) it induces thickening of the axons (channels of communications for rational thought) and increases "noise" or random neural vibration that disrupts normal mental functions and (d) more specialized functions increases the problem of connectivity.

Moreover, M. P. van den Heuvel found that shorter paths (neural connections) between brain sections correlated with higher IQ (Lapidarium Notes, n.d.). Thus, optimal intelligence is at the balance between size and quality. (It should be noted that Isaac Newton had exceptionally small brain but he was a genius).

4.2. Reception and Conversion

We trace the flow of signals (units of information) from the external world. A sense organ has two components, receptor of visible signals and convertor to brain waves transmitted to the CIR through neural bundles. The external signals encoded on sound and electromagnetic waves, superpose on the natural vibration of the receptor turning them into brain waves. In some sense organs the receptor and convertor are one, in others separate.

Consider the organ of taste, the tongue. Its receptor, consisting of separate groups of taste buds along its edge determined and differentiated by their vibration characteristics resonate with and encode brain waves generated by food molecules of corresponding tastes, in accordance with the Resonance and Internal-External Dichotomy Laws. The most accurate medium for molecular vibration is liquid, e.g., saliva. Take a sugar molecule. It is soaked in saliva so that molecular vibration is transmitted to, resonates with and vibrates the taste buds for sweetness attached to the nerves at their base. The vibration characteristics of brain wave encoded by sugar molecule superpose on the natural vibration characteristics of each taste bud for sweetness so that they get encoded on the natural nuclear vibration of the nerve fibers (neural chains) at its base and transmitted to the CIR through bundles of neural chains. Upon entry in the CIR the bundles activate a primitive nodal region and compose the appropriate neural network there that models the taste including flavor and texture. Thus, its vibration characteristics may have come from different sense organs. In this example, the taste bud is both receptor and convertor of visible signals.

In hearing the convertor is separate from the receptor. The eardrum is receptor of ordinary sound waves. The outer ear catches and directs sound waves to the eardrum which vibrates it by resonance. On the other side of the eardrum is the inner ear consisting of the cochlea, a spiral canal filled with liquid. Near the eardrum immersed in this fluid are the three tiniest bones in the body: the malleus (hammer); one end close to the eardrum; the incus (anvil) close to and beneath the other end. The stapes (stirrups) floats on the cochleal liquid near the anvil as stabilizer and modulator to minimize distortion. They are in triangular arrangement that detects where the sound is coming from. Strands of hair sticking out of the inner ear canal grouped according to vibration characteristics line the interior of the cochlea. Sound waves from external source vibrate the eardrum and the hammer the hammer and the latter vibrates the incus and the stapes near it. The stapes stirs the cochleal fluid,

stabilizes the vibration and propagates it. The latter resonates with and vibrates the corresponding strands of hair that line the inner wall of the cochlea with characteristics induced by the signals. Their nuclear vibration encodes the vibration characteristics on the nerve endings that transmit electromagnetic waves turning them to brain waves that carry and transmit information to the CIR through neural bundles (nerves) for activating a corresponding neural network. In this case, the hair strands are the convertor and the eardrum the receptor.

Molecules from source of smell, e.g., air and water, get in contact with the *cilia* ((patch of hair), the receptor, and encode and superpose their vibration characteristic on cilla's normal vibration characteristics turning them to brain waves. Thus, the *cilia* are both receptor and convertor of smell.

Consider a simple event – fire cracker explosion. It triggers sight (color, shape and extent), hearing and odor and, perhaps, heat and pressure sensations. Photons of light coming from the explosion ride on bundle of electromagnetic waves and hit the cornea where refraction starts. The bundle hits the *iris* that controls intensity (size of bundle) of light that passes through the *lens* behind it. The latter focuses the bundle and directs it to the surface of the retina, the ends of a fiber bundle and receptor of the retina. The bundle of electromagnetic waves encodes and superposes its vibration characteristics on the natural vibration of this receptor converting them to brain waves superposed on the optic nerves at the other ends of the bundle and are to the CIR. Thus, the retina is both receptor and convertor.

4.3. Sensation and Cognition

Coming from the same event the bundles of brain waves from the explosion entering the other sense organs join up into a common bundle before reaching the CIR, each sub-bundle encoded with the same vibration characteristics coming from a sense organ. The first inactive neurons in the CIR hit by this bundle activate a common set of initial neurons that form part of the *primitive nodal region* and superpose each common brain wave vibration characteristics on the normal vibration of a bundle of neural chains issuing from this nodal region. Any neural chain that has been activated and its natural vibration superposed with this brain wave vibration characteristics will resonate only and allow passage of brain waves of the same vibration characteristics. The other bundles of brain waves will activate similar bundles of neural chains each forming a branch of a *tree*. A neuron or neural chain is activated once vibrated by external brain waves (via resonance) or brain waves projected by the CIR. There is sensation as long as signals from the event keep coming. However, the signals from an event do not come at the same time. There is sensation while the signals keep coming. The number of neural chains in a bundle of the same vibration characteristics is proportional to the intensity of the signals. When signals come at high intensity the branches of the tree it activates consist of bundles of neural chains each chain having the same vibration characteristics. The corresponding sensation is also intense. The vibration of the tree caused by the event continues after the event when the sensations give way to the concept they define. At this time each bundle reduces to a single neural chain so that each tree branch is no longer a bundle of neural chains but individual neural chain. This is the point of cognition that captures the appearances of the external event source of the signals. Consciousness of the concept remains until the focus of attention by the CIR moves out. Then the tree has reverted to normal vibration. When hit by suitable cosmic wave from the cosmos or agitated by the CIR and the tree is still at its primitive nodal region, the tree is activated and vibrates its encoded characteristics and the concept is recalled. Consciousness in general is due to the normal vibration of the CIR

4.4. Memory and Recollection

It is known that during sleep concepts in the CIR are transferred (usually at 90-minute cycle) to the memory channels periodically. The memory channels are sensation regions. Since the concept components or branches of its tree have different vibration characteristics they are transferred to different sensation regions via resonance. During sleep a tree is inactive since it is not in the focus

of attention by the CIR. The CIR activates primitive nodal regions by concentration and focus. We call it conscious recollection. When a primitive nodal region is activated by cosmic waves or involuntary action by the CIR the tree is only partially activated and the concept incongruous. The next law of thought makes recollection possible.

2* *Through the CIR, thought has the innate ability to concentrate and focus on and agitate a nodal region the effect of which is to agitate a concept's components and recall them to that nodal region where they are recomposed as the original concepts or tree.*

Natural laws apply to processes in the brain. In the sensation regions a concept's components are deactivated (low kinetic energy). When its primitive nodal region is vibrated or agitated (imparted with high kinetic energy) the agitation transfers to the concept components in the sensation regions through connecting neural chains and agitate and recall them to its primitive nodal region where it is recomposed. This completes the cycle of a concept from its formation, deactivation, committing it to memory by the transfer of its components to the respective sensation regions and recollection to its primitive nodal region. The concept is again de-activated by being out of focus of attention of the CIR and transferred to memory in due course. Occasionally, a primitive nodal region is hit by suitable cosmic wave that agitates it and its component trees in the sensation region recalling and reconstituting them back at it. This is a case of spontaneous recollection, e.g., spontaneous thought of a long forgotten friend.

Recall and dispersal of concept components to and from its nodal region involve passage of energy from activated (high energy) to non-activated (low energy) and quite analogous to passage of liquid from high to low pressure. Moreover, passage of brain waves is simultaneous with outward projection of thought. During sleep the CIR, is *relatively* more agitated (more energetic) than the sensation regions due to the impact of cosmic waves (the basis of dreams); it is during this period that concept components generally transfer to the sensation regions. In conscious recollection the sensation regions are activated by the agitation of the nodal regions of the concepts by the CIR; in spontaneous recollection by cosmic waves from the cosmos. In either case, the concepts' components are recalled by the resulting agitation of their components in the respective sensation regions. Recollection of event of the past is enhanced by association with events contiguous to it due to the activation of greater neural connections that vibrates primitive neural region. There is recent ample verification of brain waves as physical concept. Thought can now activate prosthetic arm motor, run electronic wheelchair and command the computer curser to hit icons. The content of dreams is culture based because it is drawn from one's experience, creativity, rational thought and even aspirations. This should provide a basis for interpretation of dreams. Consciousness is due to normal neural vibration of the CIR sustained by impact of cosmic waves.

4.5. Creativity

The next law is the basis of creativity and abstraction.

3* *Through the CIR, thought has the ability to create abstract or non-physical concepts, i.e., concepts that have no physical referents and are not induced by sensation such as mathematical concepts, e.g., time, distance dimension*.

This law says that the CIR has innate ability to agitate and create primitive nodal regions and their trees, connect them to a higher nodal region and form a complex concept or neural network the essence of creativity.

A concept is complex if at least one of its branches is a tree. Any activity of the CIR that activates a *new* neural chain, a tree or a complex concept is creative. Creativity includes inventiveness, ingenuity, deductive reasoning that leads to new results and, most of all, rational thought that activates *new* neural chains, connections and network. Recollection is not creative but learning that comes from original research is. The primary components and core values of thought are creativity and critical thinking. However, intelligence is acquired through formal training and self-training, experience and study. For example, until recently mathematicians relied on formal

logic for drawing out conclusions from a mathematical space. It is flawed since it has nothing to do with the axioms. This flaw is the main source of error and inadequacy of traditional mathematics which has now been rectified by rational thought that anchors it solely on consistent axioms. Creativity is the thought's capability to compose concepts and neural networks that make sense, i.e., they are defined by the axioms or natural laws.

By combining a simple concept with other concepts, i.e., linking its primitive nodal region with neural chains to other nodal regions, simple or complex, thought composes complex concepts and constructs mathematical spaces and physical theories. A mathematical space is built on basic premises or axioms, physical theory on natural laws. Building them is creativity developed through formal training and self-training, peer pressure, experience and study. Qualitative mathematics is the only available tool for thought in the pursuit of science and spotting errors and contradictions. Knowledge is articulated by physical theory.

A concept of higher complexity is formed by connecting several primitive or higher nodal regions by a bundle of neural chains to a higher nodal region to form a more complex concept so that, in effect, every tree at a lower nodal region is connected to the higher nodal region. Connecting a lower nodal region to a higher nodal region involves activating the bundle of neural chains that connects them. In effect, every primitive or complex concept at lower nodal region is connected by a bundle of neural chains through the intermediate nodal regions that merge into a bundle of neural chains connected to the higher nodal region. Thus, concepts are arranged in hierarchical order in a pyramidal structure with the apex its central nodal region. When a nodal region is agitated by the CIR all nodal and sensation regions connected to it are agitated. Concept components in the sensation regions are activated and their branches recalled and recomposed one at a time from the lowest nodal regions to the apex. Sometimes a concept may not be recalled at all due to long period of non-agitation and remains in the subconscious but psychologists have devised techniques for activating it. They can also block out entire network and create amnesia.

4.6. Rational Thought, Mathematical Space and Physical Theory

When the central nodal region of a neural network includes some consistent mathematical axioms the network is a mathematical space. Every concept is defined by the axioms. Undefined concept is inadmissible because it brings in ambiguity and collapses the space. While a concept may be initially undefined, the choice of the axioms is not complete until all concepts are defined. The choice of axioms of a mathematical space is arbitrary depending on what it is intended for. However, once chosen the mathematical space becomes deductive where all conclusions follow from them. Thus, its logic or reasoning to obtain conclusions (rules of inference) is rational thought and universal rules of inference, e.g., formal logic, are not valid since they have nothing to do with the axioms. Mathematics is not a science since its subject matter is its structure and not nature. It is the appropriate language of science and its concepts have no physical referents but created by thought.

A physical theory articulates scientific knowledge. Any part of it can be activated to assist research and applications. All requirements of a mathematical space apply to physical theory. In particular, its logic or reasoning is rational thought. Such articulation can be filed in the computer any part of which can be opened to assist research and applications. In the theory of intelligence the axioms are natural laws including those specific to it that we call laws of thought. We define *value* as one's way of making a choice or decision under given situation or hypothesis, e.g., making conclusion. Making inferences or conclusions is connecting the nodal region of the hypothesis by neural chains to the nodal region of the conclusion that activates it. The choice of conclusion among possible trees or network depends on the operative value. If it is rational thought the choice follows from the axioms. In creative composition of concept trial and error is involved but its correctness is determined by the axioms. The proof of a theorem is a finite sequence of arguments that end up in the conclusion. In the CIR this corresponds to a finite sequence of nodal regions of the arguments.

Thought has the capability to activate a primitive nodal region and network of simple or complex concepts. Then it can create a "higher" nodal region that connects the first concept by a bundle of

neural chains each connected to every component of this concept through its primitive nodal region. It can further create a simple or complex concept at this higher nodal region that, together, forms a complex concept, complex because there is more than one simple concept there. It is creative and there is not necessarily causal or logical relation between a concept at the original primitive nodal region or any nodal region and a concept at a higher nodal region. It is simply a mapping.

In deductive reasoning one starts from the nodal region of the hypothesis and activates a bundle of neural chains to the *lower* nodal region of the possible conclusion where its concept components are recalled and composed. The actual choice of the correct conclusion, if any, is guided by one's value determined by formal training and self-training, peer pressure, culture and experience. When no correct conclusion is found, either the hypothesis is incorrect or the concepts at the lower nodal region are inadequate in which case creative formulation of the correct conclusion (or conclusions) is needed. At any rate, the direction of thought (from higher to lower nodal region) is the reverse of inductive reasoning and the direction of thought can go either way. When a nodal region is agitated the agitation passes through every chain connected to it. In a physical theory, the choice of the axioms is limited to natural laws which are also creatively and inductively formulated based on observation and synthesis of relevant natural phenomena, available information, experimentation and rational thought. Thus, a natural law has no physical referent (one does not find it on the street) but results from analysis of natural phenomena through rational thought. Clearly, a mathematical space or physical theory has higher nodal region than any of its concepts.

Consider a physical theory as complex concept modeled in the CIR by a pyramidal hierarchy of concepts its (central) nodal region at the apex. The components of a tree, simple or complex, are joined by neural bundle through its nodal region to a higher nodal region where it joins with other neural bundles that connect them through intermediate higher nodal regions to the central nodal region of a physical theory.

In multidisciplinary research a number of physical theories and their primitive nodal regions are joined together by activated neural bundles of neural chains to their respective central neural regions and, therefore, to their super central nodal regions (multiple interconnection). In turn, the central nodal regions are joined by these neural bundles to the super central nodal region of these theories. The entire network from the super nodal region down to the primitive nodal regions can be programmed, formatted properly and entered into the computer database any part of which can be viewed at will.

In inductive reasoning a neural chain to higher nodal region is activated where a component neural network is an inference. In contrast, the conclusion in deductive reasoning is a necessity determined by the axioms and where the neural chains go from higher to lower nodal regions. All mental activities that make up qualitative mathematics belong to intelligence. However, one's intelligence is not inborn but comes from formal training, self-training, peer pressure, experience, and research. This applies to one's way of thinking.

Every field of natural science and mathematics has a central nodal region to which all neural chains of concept components at lower nodal regions are connected by neural bundles down to their primitive nodal regions. In turn, the central nodal regions of the various fields of science and mathematics are connected to each other through a super nodal region. This allows the CIR to activate a specific nodal region and its neural network and concepts when needed. For instance, a physicist may activate a specific neural network of mathematics through its central nodal region as needed. The entire interdisciplinary network can be programmed into the computer where the researcher using it is the counterpart of the CIR.

Thought, particularly, research that involves creative activity raises the level of neural network connections and deepens, enhances grasp of the subject matter and broadens knowledge. Creative mental activity enhances neural connections that raise the capability of the brain described as *wisdom*. Sustained involvement in rational thought and new physical activity is the antidote to the

normal narrowing of the brain that comes with aging that can lead to senility, amnesia or, in its most severe form, dementia or even Alzheimer's disease. Enhanced neural connection retains the normal functions of the brain, particularly, its primary function of control over body processes that a person who remains mentally active enjoys relatively good mental and physical health in their 80s and 90s.

This is supported by scientific study. Among the notable mathematicians known to be mentally active in their 90s (not necessarily in mathematics) were Bertrand Russell (philosopher) 96; John Littlewood (mathematician), 96; and L. C. Young (mathematician) 95.

Short of physical theory a discipline of science is a hodgepodge of information and experimental data and even with a physical theory in each discipline but short of integration into GUT human knowledge is a disparate cluster of specialized knowledge. True to its name GUT binds the clusters together into a unified physical theory at its super central nodal region with physics as its truly basic discipline that lies at the heart of natural science.

4.7. Perception

The CIR can recall and recompose concept components at their nodal regions. Psychologists tell us that one's perception of event comes mainly from memory, only 20% from events external to the sense organs. They use this information to reveal the contours of one's personality and his life experience by asking the subject to tell what he perceives from a set of objects.

How does intelligence work in practical affairs? During, say, a game of bowling the player models the lanes at a central nodal region by appropriate neural network where the nodal region of the lane is the focus. The player commands the body to play the game on the basis of his perception of the lane, knowledge of the game and previous experience. A skillful bowler accurately models the lane on the basis of which the CIR commands precise execution. Even more amazing is how a violinist, i.e., his CIR, models and coordinates playing fine music. Although reflex does most of it the CIR monitors and is in command. In any physical endeavor thought gives command through brain waves that activate appropriate parts of the body to execute. Sometimes thought triggers automatic execution. For instance, when one thinks of lemon brain waves agitate and convert superstrings to saliva in the salivary gland.

Stress dulls the ability of the brain to do its main function as control center of body functions and processes, particularly, the proper functioning of the immune system. For example, under stress it is unable to do its normal function of destroying unwanted systems. Ordinarily, the body has tolerable level of cancer cells that the immune system adequately maintains. However, under stress, it fails and is overcome by their replication and the individual becomes sick. Thus, healthy body and mind go together. In some cases extreme stress may cause physiological imbalance that results in depression and the individual suffers from visual or vocal hallucination or makes unusual decision, e.g., suicide attempt. Such imbalance may be due to a gene created by emotional trauma (Escultura, 2012b). In general, strong emotion is accompanied by physiological changes, e.g., raised adrenalin secretion associated with anger or fear. Strong sensation may also cause physiological changes, e.g., extreme pain produces molecule in the neural membrane (Osipenko et al., 1999; Krylov & Shehegelov, 1999). Physical processes in the brain involved in mental activity have been quantitatively modeled (Pokrovsky, 1989a, 1989b, & 1996). When the CIR lacks ability to direct or control focus or concentrate the person suffers from a condition called autism. In one form the person is simultaneously aware of everything around him and cannot respond properly. Naturally, he has short attention span, since other sensations compete for attention, and becomes hyperactive (therapy can now control this condition).

4.8. Learning

Learning is not only fitting new concepts, information, etc., into knowledge in one's thought but also storing their components in the appropriate sensation regions; if the latter is not recalled then

nothing is learned. A normal mind is both selective and focused. It entertains only very few signals from the external world. Still fewer is registered and retained as memory. What is the basis of long-term memory? It is resonance in the broad sense, i.e., new information is learned or retained when it fits a knowledge system in thought based on qualitative modeling or values particular to it. This process involves neural network encoding, an active mental activity requiring concentration.

Moreover, information that requires deep concentration to understand and integrate into a knowledge system is never forgotten once grasped. The vastness of neural interconnections required for it enhances recollection. One technique for enhancing retention is listening to and concentrating on the lecture without taking notes which can be distracting but grasping the lecture thoroughly and asking questions to deepen it and expose ambiguity or contradiction if any (critical thinking). This induces extensive neural interconnections that facilitate recollection. This is probably the reason a student who struggles to overcome great adversity, has no time to review his notes and strives to grasp the lectures instead is usually a good learner and achiever. Of course, another learning enhancer is creativity that happens in research.

Critical thinking and creativity triggered critique-rectification of foundations and the real and complex number systems that resolved FLT in 1998 (Escultura, 1998, 2009b, & 2013d) and development of the new real number system and complex vector plane (Escultura, 1998 & 2013d). It was the critique-rectification of physics that led to the solution of the gravitational n-body problem in 1997 (Escultura, 1997) and catalyzed development of GUT. In physics, critique of its foundations revealed inadequacy of quantitative modeling that was rectified by QMAM.

4.9. Learning Principles

We identify learning principles with practical applications for mathematics-science education. We first summarize some learning principles (Escultura, 2012b & 2014b).

Learning-Efficiency-Memory Principle. *Learning efficiency is in direct proportion to the level of memory in thought.*

Principle of Complexity and Retention. *Learning effectiveness increases with the level of complexity of the Subject matter and mental processing required; the more complex the subject matter the higher the level of concentration needed to understand it, the more extensive interconnections among nodal regions and the longer the retention.*

One's ability to concentrate is enhanced by serious thought and deep concentration in the midst of great distraction. This was done by the tennis champion Agassi to enhance his reflexes and skill. During high school the author resided next door to the noisy power plant and before the computer became a household item drafted his papers in noisy coffee shops instead of the deafening silence of the study room. All of these raised the power of concentration.

The rate of learning graph as a function of time approximates the logarithmic curve that tapers off away from the origin which reflects the law of diminishing return; as the brain gets tired, thought loses concentration and learning drops to zero. When learning requires high level of concentration due to the complexity of the subject matter greater activation of neural connections occurs and the rate of retention graph rises towards a vertical asymptote at the completion of the learning process signifying almost permanent retention or memory. This is true of complicated scientific analysis or principle. When learning involves only mechanical activity, e.g., card concentration game, the curve drops to zero when the activity stops, i.e., there is no retention.

Learning and Resonance Principles and Recollection. *Thought only retains information that makes sense, i.e., fits some knowledge and, in mathematics or science, processes only information that fits some mathematical space or physical theory.*

There are, of course exceptions, like trivia, where there is motivation to win a TV quiz prize. Retention is also enhanced by the number of sensations involved in the course of learning

something. Thus, the rationale for multi-media teaching aids involving sight, hearing and touch (hands-on). Learning is not creative unless it is the result of original research. Frontier research is creative in fields that are not well explored; otherwise, results are hard to come by. Recollection is not learning but it increases receptiveness to related incoming information and enhances learning. Quite often the incoming information triggers recollection. Absent-mindedness is due to low level of concentration at the time of encoding. For instance, one picks up an umbrella as reflex action to rain; he is likely to leave it in the bus when rain stops. Well-grasped complicated subject is easy to recall due to enormity of interconnected network involved. Activation of one network triggers activation of others connected to it.

Principle of Association and Neural Network Interconnection. *The more interconnected and contiguous the encoded neural network is the easier and more precise the recollection.*

Learning occurs not only through cognition of similarity and regularity of patterns but also through comparison and contrast by drawing out extreme situation and dramatizing the effect or impact of opposite conclusions. Stressing a point and reducing an undesirable conclusion to absurdity are among the practical tactics for effective teaching. They broaden neural bundle activation and enhance permanency of retention. At the same time, reduction to absurdity or contradiction including the use of counterexample jolts thought into recognition of error and negation of a particular proposition which pave the way for rectification that opens up new fields. For example, for almost a century since David Hilbert, no one noticed that the statement "0.99… = 1" is false but it is since it is akin to the statement "orange = apple" that equates distinct objects. This realization triggered the critique of the real number system and its rectification as the new real number system that yielded the counterexample to Fermat's last theorem (Escultura, 1998; 2009b). All of them are subsumed under critical thinking. Its effect is to raise the level of neural interconnection and enhance the ease of recollection and clarity of details. Conversely, concepts not recalled for a long time are likely to be drawn into the subconscious. Physically, this means that when the associated neural network remains non-agitated for a long time, it becomes difficult to agitate and retrieve the information encoded in it. This is analogous to the phenomenon of atrophy. Psychologists have devised techniques for drawing out information from the subconscious or, perhaps, blocking off unpleasant memory. In the former it amounts to increasing contiguous concepts around the information and, in effect, raising the intensity of agitation. In the latter it amounts to altering the recollection of a previous event. This is not unusual. In some cases, suitable psychological technique can make an innocent person confess to a crime he did not commit thinking that he did. Constant repetition of a lie may cause it to be perceived as truth. This was used by the protagonists during the Second World War and the Cold War.

Structure and coordination of knowledge. *A discipline of knowledge is encoded as system of neural network with interconnected nodal regions connected to a central nodal region. Different disciplines have interconnected central nodal regions; each autonomous but can be activated fully or partially. However, they are bound together and connected to the super central nodal region through which any part of the whole network can be activated.*

Since neural network is a physical entity encoded with vibration characteristics it is ultimately genetically encoded and when the neurons die the encoded information (vibration characteristics) is passed on to the replacement. This is also the basis of memory. Thus, the physical components of the hunting skill of the female lion are in the gene (Escultura, 2015a & 2015b). However, the female cub needs training to actualize it. Therefore, mother lion borrows the cub of a prey in the morning for training the cub and returns it to its den in the afternoon to mature and become a prey (Escultura, 2010a, 2015a, & 2015b). An example of physical characteristic that enhance mental skill is the cosmic intensity threshold for activating a network. Another is the encoding sensitivity of the neurons. Persons with photographic memory have high encoding sensitivity and low degradation of neural vibration characteristics. This information might have implications for the study of intelligence and learning capability.

There are rare cases where neural network interconnections are genetically encoded, not just the physical characteristics of the neurons. An example is Devi Shakuntala's ability to compute huge numbers up to 13 digits faster than the computer and yield the result automatically without her really knowing how she did it. The only plausible explanation is there was in her cortex suitable interconnected neural network that got activated and carried out the computation automatically as soon as the numbers were fed in the same way reflex is activated by certain stimuli. This is analogous to the existence of a "survival module" in the cortex, which is genetic, that gets activated when the person goes through a life threatening situation. The person acquires special skills, e.g. facility with numbers and musical skill. Like reflex such skill is genetic. After all, the synapses that join the dendrites are determined by some genes. Such exceptional ability is likely to arise in old cultures due to genetic acquisition and evolutionary advance. Devi Shakuntala was an Indian and India has the oldest culture going back to 26000 BC (Lakshmikantham, 1998, 1999).

Note

▪ What is the significance of the jelly-like texture of the brain? Jelly has the unique property of being both brittle and elastic. A strictly brittle material cracks when vibrated and only elastic material vibrates. But brittle material retains impressions. Jelly is elastic within the high frequency (short wavelength) range and tiny amplitudes of electromagnetic and brain waves. Thus, it retains encoded vibration characteristics while it vibrates at the same time so that it accommodates all mental activities.

▪ There are many child prodigies in mathematics and senior wranglers (top scorers) of the tripos examinations in mathematics at Trinity College, Cambridge University, England. With the exception of John Littlewood who was a senior wrangler, none of them became great mathematician (Escultura, 2009b & 2013d). The main achievement of one of the child prodigies, Kurt Gödel, namely, the Incompleteness Theorems, is flawed (Gödel, 1931). The wranglers, L. C. Young, 3rd and Bertrand Russell, 4th were great achievers. The child prodigies excelled in computation which is mechanical and a tiny cog in rational thought. The great achievers are those who trained well in rational thought.

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