

Self and Binding: Part II

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Abstract

This chapter is second part of a representation devoted to the notion of self as it is understood in TGD framework.

The possibility of negentropic entanglement has profound implications. It leads to a vision about learning as a basic quantum process possible in the intersection of real and p-adic worlds and made possible because state function reduction ceases to be a random process for negentropically quantum states. Quite concrete ideas about the role of synaptic transmission and neural transmitters for consciousness emerge. Music experience provides an especially interesting application for the vision about consciousness and zero energy ontology together with number theoretical vision inspires several concrete interpretations. Synchronous firing of neurons- in particular at 40 Hz frequency- is an attractive correlate for the negentropic entanglement and synesthesia can be interpreted as a particular manifestations of negentropic entanglement.

In TGD framework it is not at all obvious that the highest levels of our personal self hierarchy should correspond to the size of the physical body. Various empirical facts, in particular the observations related to the special effects of excitations of geomagnetic fields and ELF em fields in EEG frequency range on brain, inspire the hypothesis that our selves correspond to topological field quanta of em fields associated with EEG frequencies and thus by Uncertainty Principle have size scale of Earth. Indeed, the notion of magnetic body as a space-time correlate of self has become a key concept in TGD inspired biology. Magnetic body carrying dark matter identified as large h_{eff} phases can be seen as intentional agent using biological body as motor instrument and sensory receptor.

1 Introduction

The conflict between the non-determinism of state function reduction and determinism of time evolution of Schrödinger equation is serious enough a problem to motivate the attempt to extend physics to a theory of consciousness by raising the observer from an outsider to a key notion also at the level of physical theory by bringing in the notion of self. Further motivations come from the failure of the materialistic and reductionistic dogmas in attempts to understand consciousness in neuroscience context. There are reasons to doubt that standard quantum physics could be enough to achieve this goal and the new physics predicted by TGD is indeed central in the proposed theory.

1.1 Zero Energy Ontology

Zero Energy Ontology (ZEO) was forced by the interpretational problems created by the vacuum extremal property of Robertson-Walker cosmologies imbedded as 4-surfaces in $M^4 \times CP_2$ meaning that the density of inertial mass (but not gravitational mass) for these cosmologies was vanishing meaning a conflict with Equivalence Principle. In ZEO physical states are replaced by pairs of positive and negative energy states assigned to the past *resp.* future boundaries of causal diamonds (CDs) defined as intersections of future and past directed light-cones ($\delta M_{\pm}^4 \times CP_2$). The net values of all conserved quantum numbers of zero energy states vanish. Zero energy states are interpreted as pairs of initial and final states of a physical event such as particle scattering so that only events appear in the new ontology.

ZEO combined with the notion of quantum jump resolves several problems. For instance, the troublesome questions about the initial state of universe and about the values of conserved quantum numbers of the Universe can be avoided since everything is in principle creatable from vacuum. Communication with the geometric past using negative energy signals and time-like entanglement are crucial for the TGD inspired quantum model of memory and both make sense in ZEO. ZEO leads to a precise mathematical characterization of the finite resolution of both quantum measurement and sensory and cognitive representations in terms of inclusions of von Neumann algebras known as hyperfinite factors of type II_1 . The space-time correlate for the finite resolution is discretization which appears also in the formulation of quantum TGD.

ZEO (ZEO) means that one must distinguish between M -matrix and U -matrix. M -matrix characterizes the time like entanglement between positive and negative energy parts of zero energy state and is measured in particle scattering experiments. M -matrix need not be unitary and can be identified as a “complex” square root of density matrix representable as a product of its real and positive square root and of unitary S -matrix so that thermodynamics becomes part of quantum

theory with thermodynamical ensemble being replaced with a zero energy state. The unitary U -matrix describes quantum transitions between zero energy states and is therefore something genuinely new. It is natural to assign the statistical description of intentional action with U -matrix since quantum jump occurs between zero energy states.

Quantum measurement theory based on ZEO can be said to imply the notion of self and to explaining basic aspects of consciousness when one includes also the hierarchy of Planck constants characterizing hierarchy of quantum criticalities. At the imbedding space-level CD is the correlate of self whereas space-time sheets having their ends at the light-like boundaries of CD are the correlates at the level of 4-D space-time. The hierarchy of CDs within CDs corresponds to the hierarchy of selves. Zero energy ontology leads also an argument explaining why the arrow of subjective time induces an apparent arrow of geometric time as a result if intentional action and why the contents of sensory consciousness is restricted to such a narrow time interval (located near the future boundary of CD).

1.2 Hierarchy Of Planck Constants

The hierarchy of Planck constants corresponds to a hierarchy $h_{eff} = n \times h$ [K13, ?, K33]. The original hypothesis was that it corresponds to a hierarchy of singular coverings of imbedding space $M^4 \times CP_2$ - or rather - given causal diamond (CD).

The recent view is that there is a hierarchy of quantum criticalities such that the sub-algebra of super-symplectic algebra for which conformal weights are n -ples of those for the entire algebra acts as conformal gauge symmetries at given level. Due to the resulting non-determinism the space-time surfaces connecting 3-surfaces at the opposite boundaries of CD are gauge degenerate and there are n conformal equivalence classes analogous to sheets of Riemann surface of $z^{1/n}$. This view has far reaching consequences. The hierarchy of quantum criticalities has an interpretation as that for macroscopic quantum phases and the phase transitions increasing n to its multiple occur spontaneously and generate also negentropy if NMP is assumed. Hence evolution can be seen as a gradual reduction of criticality occurring unavoidably.

An alternative formulation [K27, ?, K33, K32] emerged in terms of gravitational Planck constant $h_{gr} = GMm/v_0$, where v_0 is characteristic velocity in the system consisting of two masses involved, introduced originally by Nottale [?] h_{gr} would be associated with the flux tubes connecting the two masses. Later it became clear that the identification $h_{eff} = h_{gr}$ leads to considerable insights in biology: in particular bio-photons can be identified as ordinary photons resulting from dark cyclotron photons with a universal energy spectrum.

The book metaphor inspired by the original view about hierarchy of Planck constants is however very useful. The value of the Planck constant characterizes partially given page and arbitrary large values of \hbar are predicted so that macroscopic quantum phases are possible since the fundamental quantum scales scale like \hbar . All particles in the vertices of Feynman diagrams have the same value of Planck constant so that particles at different pages cannot have local interactions. Thus one can speak about relative darkness in the sense that only the interactions mediated by the exchange of particles and by classical fields are possible between different pages. Dark matter in this sense can be observed, say through the classical gravitational and electromagnetic interactions. It is in principle possible to photograph dark matter by the exchange of photons which leak to another page of book, reflect, and leak back. This leakage corresponds to \hbar changing phase transition occurring at quantum criticality and living matter is expected carry out these phase transitions routinely in bio-control. This picture leads to no obvious contradictions with what is really known about dark matter and to my opinion the basic difficulty in understanding of dark matter (and living matter) is the blind belief in standard quantum theory.

1.3 P-Adic Physics As Physics Of Cognition

p-Adic mass calculations relying on p-adic length scale hypothesis led to an understanding of elementary particle masses using only super-conformal symmetries and p-adic thermodynamics. The need to fuse real physics and various p-adic physics to single coherent whole led to a generalization of the notion of number obtained by gluing together reals and p-adics together along common rationals and algebraics (see fig. <http://tgdtheory.fi/appfigures/book.jpg>, which is also in the appendix of this <http://tgdtheory.fi/appfigures/book.jpg>). The interpretation of p-adic

space-time sheets is as correlates for cognition. p-Adic and real space-time sheets intersect along common rationals and algebraics and the subset of these points could be called intersection of realities.

In fact, the intersection can be interpreted in more abstract sense at the level of WCW as surfaces for which parameters (WCW coordinates) are such that the interpretation both as real and p-adic surface is possible. In this manner one avoids discretization at space-time level. It has turned out that string world sheets and partonic 2-surfaces with defining parameters in an extension of rationals define naturally the intersection and strong form of holography allows the continuation of these 2-surfaces to space-time surfaces.

The outcome is a vision about hierarchy extensions of rational numbers defining an evolutionary hierarchy. So called ramified primes associated with the extension define preferred primes identifiable as p-adic primes and weak form NMP allows to understand p-adic length scale hypothesis and its generalization stating that primes near powers of primes are favored by NMP.

There exists an infinite hierarchy of number theoretical entropies making sense for rational or even algebraic entanglement probabilities. In this case the entanglement negentropy can be negative so that NMP favors the generation of negentropic entanglement, which need not be bound state entanglement in standard sense. Negentropic entanglement might serve as a correlate for emotions like love and experience of understanding. The reduction of ordinary entanglement entropy to random final state implies second law at the level of ensemble. The generation of NE as the outcome of the reduction is not totally random process: the prediction is that second law need not universal truth holding true in all scales. To avoid making wrong conclusions about NMP, one must keep in mind that entanglement entropy is two-particle property whereas thermodynamical entropy is single particle property.

Quantum measurement theory allows only final states, which have density matrices which are projectors so that the rational entanglement probabilities $p = 1/n$ are identical in this case. If the prime p divides n , one obtains negative entanglement entropy and one can say that entanglement is negentropic. Negentropy is largest for the largest power of prime dividing n and one could define entanglement entropy as that associated with this prime.

1.4 NMP

One obtains standard quantum measurement theory by assuming that the density matrix of the sub-system is the universal observable. In state function reduction this observable is measured and the system goes to an eigenstate of it. It can however happen that the eigenvalues are degenerate and in this case one can ask whether the reduction leads only to an eigen space so that entanglement characterized by a n -dimensional projection operator remains.

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Negentropy Maximization Principle (NMP) [K20] codes for the dynamics of standard state function reduction and states that the state function reduction process following U -process gives rise to maximal reduction of entanglement entropy - or equivalently - gain of entanglement negentropy - at each step. In the generic case this implies decomposition of the system to unique unentangled systems and the process repeats itself for these systems. The process stops when the resulting subsystem cannot be decomposed to a pair of free systems since energy conservation makes the reduction of entanglement kinematically impossible in the case of bound states.

The interpretation is that NMP favors generation of negentropic entanglement (NE). One can of course argue that the generation of this kind of entanglement is extremely improbable. The hierarchy of Planck constants involving quantum criticality could however provide the manner to generate it.

TGD inspired theory of consciousness forces to challenge the hypothesis that NMP always forces the state function reduction to the sub-space defined by the projector with maximal dimension appearing in the decomposition of the density matrix. NMP would not allow the self to make choices, which are bad deeds in the sense that they do not increase maximally the negentropic resources of the Universe. We would live in the best possible Universe becoming better all the time. This is obviously too good to be true.

The weak form of NMP allows the choice leading to maximal negentropy gain but allows also those choices for which the reduction occurs to a sub-space of the space defined by projector. When

this sub-space is 1-dimensional standard quantum measurement results and the self is isolated from the target of observations. Negentropic entanglement has interpretation as attention with positively colored contents of consciousness. Experience of love would be one attribute of this kind of state. Weak form of NMP would be like God allowing the sinner to choose between Good and Evil.

Weak form of NMP turns out to have surprisingly strong consequences. For instance, by choosing the sub-space to have dimension given by power of prime, the state function reduction can yield a larger negentropy gain than otherwise. Primes near powers of prime as dimensions of final state projector are optimal from the point of view of evolution since they give a large negentropy gain and generate large p p-adicity, which means higher evolutionary level in number theoretical sense: this result is nothing but a generalization of p-adic length scale hypothesis.

NMP generalizes also so that it applies to hyper-finite factors of type II_1 and also in this case it is possible to define negentropic entanglement. In this case entanglement negentropy is positive because the projector for the sub-space as dimension smaller than one as the inverse of the index of inclusion. The interpretation is that the degrees of freedom below measurement resolution carry NE characterized by the projector to the sub-space.

1.5 The Notion Of Self

The quantum notion of self solved several key problems of TGD inspired theory of consciousness but the precise definition of self has remained a long standing problem and I have been even ready to identify self with quantum jump. Zero energy ontology allows what looks a final solution of the problem. Self indeed corresponds to a sequence of quantum jumps integrating to single unit, but these quantum jumps correspond to state function reductions to a fixed boundary of CD leaving the corresponding parts of zero energy states invariant. In positive energy ontology these repeated state function reductions would have no effect on the state but in TGD framework there occurs a change for the second boundary and gives rise to the experienced flow of time and its arrow and gives rise to self. The first quantum jump to the opposite boundary corresponds to the act of free will or wake-up of self.

p-Adic physics as correlate for cognition leads to the notion of negentropic entanglement possible in the intersection of real and p-adic worlds involves experience about expansion of consciousness. Consistency with standard quantum measurement theory forces negentropic entanglement to correspond to density matrix proportional to unit matrix. Unitary entanglement typical for quantum computing systems gives rise to unitary entanglement. A natural conjecture is that the integer n in $h_{eff} = n \times h$ corresponds to the dimension of the unit matrix associated with negentropic entanglement. Also a connection with quantum criticality made possible by non-determinism of Kähler action and extended conformal invariance emerges so that there is high conceptual coherence between the new concepts inspired by TGD.

The identification of the imbedding space correlate of self as causal diamond (CD) of the imbedding space combined with the identification of space-time correlates as space-time sheets inside CD solved the problems concerning the relationship between geometric and subjective time.

Subjective memory is assumed to correspond to an average of conscious experiences of quantum jumps occurred after the last wake-up of self (the first one in the sequence of state function reduction at same boundary of CD). This leads to the identification of qualia as averages of the increments of quantum numbers and zero modes in the ensemble of quantum jumps defining self. Summation hypothesis states that self X experiences the experiences of its subselves as abstracted experiences, averages X_{ij} about sub-subselves X_{ij} . Subselves of un-entangled selves can entangle (this is due to the many-sheeted sub-system concept) and this allows fusion and sharing of mental images.

Quantum entanglement provides a mechanism leading to the formation of irreducible wholes at the level of mental images. Entanglement can be entropic bound state entanglement or negentropic entanglement, which need not involve binding energy. The latter is possible only in the intersection of real and p-adic worlds where life can be said to reside. Quantum entanglement is possible also in time direction in zero energy ontology. It is tempting to assign negatively colored emotions to the entropic entanglement and positive emotions to the negentropic one. In TGD framework the standard vision about brain based on reductionistic-holistic dichotomy must be replaced with a trinity in which negentropic entanglement corresponds to a mode of cognition, which does not allow linguistic expression and episodal memories, and various mental feats of synesthetes and idiot savants could be seen as a manifestation of negentropic entanglement. Also meditative consciousness

would be negentropic.

Selves are called irreducible if they possess no subselves, otherwise reducible. Subselves correspond to mental images so that irreducible subselves possess no mental images and are in a state of pure self-awareness: it is not clear whether this kind of states are possible in practice. When the subselves of self fuse to single negentropic subself, a state of “one-ness” results in somewhat different sense. This mode of consciousness can be identified as “whole-body” consciousness and differs from ordinary consciousness during which self has large number of mental images. These modes could naturally explain emotional/holistic and rational modes of mind. These two modes could make it possible to understand various dichotomies like brain/left brain, emotional/analytic, religious/rational, Eastern/Western,... One could understand linear cognitive processes like thinking and language as self cascades in which self decomposes into subselves, which in turn decompose into subselves, which ... and self hierarchy implies connection with computationalism.

The possibility of negentropic entanglement has profound implications. It leads to a vision about learning as a basic quantum process possible in the intersection of real and p-adic worlds and made possible because state function reduction ceases to be a random process for negentropically entangled zero energy states. Quite concrete ideas about the role of synaptic transmission and neural transmitters for consciousness emerge. Music experience provides an especially interesting application for the vision about consciousness and zero energy ontology together with number theoretical vision inspires several concrete interpretations. Synchronous firing of neurons- in particular at 40 Hz frequency- is an attractive correlate for the negentropic entanglement and synesthesia can be interpreted as a particular manifestations of negentropic entanglement.

In TGD framework it is not at all obvious that the highest levels of our personal self hierarchy should correspond to the size of the physical body. Various empirical facts, in particular the observations related to the special effects of excitations of geomagnetic fields and ELF em fields in EEG frequency range on brain, inspire the hypothesis that our selves correspond to topological field quanta of em fields associated with EEG frequencies and thus by Uncertainty Principle have size scale of Earth. This leads to a rather radical modification of the brain centered views about consciousness, and one can quite seriously consider the questions like what physical death means from the point of view of consciousness: it could be that electromagnetic part of self hierarchy could survive after the physical death as a “soul”.

This chapter is devoted to the theoretical aspects related to the definition of self. In second chapter applications of the notion of self are discussed. The plan of this chapter is as follows.

1. In the first section the notion of self is defined and various aspects related to it are discussed. This includes discussion about the flow and arrow of time, qualia, quantum model for intelligent systems, emotional representation of Boolean logic, the origins of ethics and moral as NMP allows to understand them, and self referentiality. Also the general structure of conscious experience is considered: self has sub-selves experienced as mental images and sharing and fusion of mental images is possible in many-sheeted space-time. Various aspects of binding are discussed in terms of negentropic entanglement. The basic prediction is entire self hierarchy and also the aspects related to this hierarchy are discussed.
2. Second section is devoted to a critical question: is NE experienced directly or does it only define a model of self and is it necessary to have a mechanism allow to make the information in question conscious. Although the most elegant assumption is that sequence of repeated state function reductions makes NE conscious, the possibility that interaction free measurement might be needed to achieve this, is discussed.

This is the second part of the chapter devoted to the notion of self and discusses various applications of TGD inspired notion of self.

1. Some applications at brain level are considered including the differences between left and right brain hemispheres and music experience.
2. Negentropic entanglement seems to be the key to the understanding of altered states of consciousness. What I call whole-body consciousness is discussed in this framework. Also EEG synchrony and synesthesia are analyzed in terms of negentropic entanglement.

3. Higher levels of biological self hierarchy are discussed. Here the notion of magnetic body is central.
4. An attempt to understand what happens in ageing and death is made.

The appendix of the book gives a summary about basic concepts of TGD with illustrations. Pdf representation of same files serving as a kind of glossary can be found at <http://tgdtheory.fi/tgdglossary.pdf> [?].

2 Some Applications At Brain Level

In this section the notion of self and related notions are applied to brain at general level. Due to the introduction of the notion of negentropic entanglement (NE) the representation differs from the earlier one decisively. The most recent progress (2015) in understanding of ZEO, NMP, the role of NE, hierarchy of Planck constants and its correlation with hierarchy of quantum criticalities, and number theoretic universality realized in terms of adelic physics have not however been taken into account properly although I have made some comments here and there.

2.1 A Simple Model For Cognition

The hierarchy of selves and summation hypothesis allows to construct a very general model for cognitive processes including as a special case thinking, analysis of visual experience, and language. In nutshell: cognitive process could be regarded as cascade like process leading to a generation of selves followed by generation of sub-selves for these leading to.... Quantum jump becomes the building block of cognition and thought but is not sufficient alone. p-Adic space-time sheets as correlates of cognition provide geometric correlates for thoughts, intentions, plans, etc.. are a fundamental element of cognition. The longheld idea that the transformation of intention to action corresponds to p-adic-to-real transition has been given up: it is mathematically awkward and is not needed.

The intersection of real and p-adic worlds understood as partonic 2-surfaces and string world sheets allowing an interpretation in both real and p-adic sense and the intersections of real and p-adic partonic 2-surfaces consisting of rational and common algebraic points define the lowest level cognitive representations. NE is possible only in the intersection in accordance with with the vision that cognitive representations carry the information.

2.1.1 Quantum criticality of TGD and existence of selves

The model of cognition provides a new view to the role of quantum criticality of TGD. TGD Universe is like a system at a top of hill at a top of hill at.... More concretely, there is an infinite fractal hierarchy of sub-algebras of super-symplectic algebra isomorphic to the full algebra with conformal weights coming as n -ples of those for the full algebra [K13, K32, K33]. This kind of sub-algebra acts as conformal gauge symmetries at the level of criticality labelled by n . The phase transitions replacing n with its multiple occur spontaneously and one obtains infinite inclusion hierarchies with $n(i)$ dividing $n(i+1)$. These hierarchy would naturally have interpretation as inclusion hierarchies for hyper-finite factors of type II_1 [K31].

The value of Planck constant $h_{eff}/h = n$ would label these hierarchies and for large values of n one would have macroscopic quantum coherence. By NMP the first state function reduction to the opposite boundary of CD would in ZEO give rise to a phase transition increasing h_{eff} but meaning death of corresponding self and re-incarnation at opposite boundary. Selves would fight to get NE to satisfy the needs of NMP and in this manner to avoid this fatal first state function reduction. The fight for survival would allow sub-selves representing to die and born again generate NE and evolution would be the outcome. Weak form of NMP allows also reductions for which the NE is not maximal. This option is actually better concerning generation of NE.

TGD universe would be in a state of maximal alertness ready to generate cascades of selves representing cognitive acts. Our sensory and cognitive acts would be only part of those of the entire Universe proceeding from top to bottom as infinite trees with branches representing new selves and nodes representing moments of wake-ups for the selves. Or expressing it in the terminology of AI:

we would be like subprograms of infinite program represented by entire universe. The presence of higher level selves means that cognitive acts can proceed from the level of even entire biosystem to the level of DNA. This encourages to interesting speculations: for instance, the ideas of Sheldrake about learning at the level of species and even biosphere might find justification [K26].

Number theoretical criticality is an important aspect of quantum criticality and is taken to mean that life and conscious intelligence reside in the intersection of real and p-adic worlds, where discrete cognitive representations. By strong form of holography the intersection would consist of string world sheets and partonic 2-surfaces characterized by parameters in some algebraic extension of rationals defining a hierarchy. By conformal invariance the moduli spaces of conformal equivalence classes restricted to algebraic extension would define the intersections.

2.1.2 Quantum jump as cognitive process

The following scenario is a vision about what happens in cognition much before the recent progress in understanding ZEO, NMP, the notion of negentropic entanglement, and hierarchy of Planck constants labelling that of quantum criticalities and dark matter, and is therefore out-of-date at the level of details.

U process followed by a cascade of state function reductions will be identified as the basic cognitive act.

1. State function reduction can be characterized as a binary tree. At each step of the state function reduction cascade some sub-selves manage to remain unentangled, some sub-selves lose their consciousness by developing entropic bound state entanglement, or experience expansion of consciousness by entangling negentropically. A particular branch of the process stops if sub-self allows no decomposition to entropically entangled but otherwise free pieces. What is new is that the entanglement is also time-like and time-like entanglement turns out to be central for understanding of what happens in learning.
2. The binary tree of state function reduction has a natural ordering. This ordering need not have any correlate at the level of geometric time. At the level of subjective time and conscious experience the correlate for ordering could exist but if self experiences its sub-selves as averages of sub-sub-selves this cascade is experienced only partially by given sub-self. One can of course argue that self wakes up in each quantum jump separately and quantum jump sequence should be seen as a sequence of “awakenings” (I used this term earlier): this awakening is however something different from the emergence of mental image. Maybe time-like NE is which binds this sequence of “awakenings” to a continuous stream of consciousness that we experience.
3. The outcome of the state function reduction is random when it leads to un-entangled sub-self but statistical determinism implies reliability at the level of ensemble. For NE state function reduction is nearly deterministic process and in this case one can speak in reasonable approximation about an iteration of a unitary processes defined by the powers of U . This iterative process defines a self-organization process expected to be also behind learning.
4. One possible interpretation of the self cascade is as a representation for an abstraction process representing thoughts about thoughts about... Our poor ability to form statements about statements about... would correspond to the fact that self experiences only its sub-selves directly. Another interpretation is as analysis, in which initial experience gradually sharpens and gets more and more structured during the decomposition into sub-selves. Sub-selves could be thought as symbols of language or as logical statements or objects in picture: interpretation depends on what kind of cognitive process is in question. This process occurs in several time scales- even in the time scale defined by human life cycle. The modular structure of cognitive acts is also analogous to the modular structure of a computer program: starting of subprogram means the reduction of entanglement for the corresponding subsystem.

One can see this process also at the level of imbedding space correlates.

1. Selves wake up and begin to perform quantum jumps. The imbedding space counterpart for self is CD (causal diamond) characterized by time scale coming as powers of two and

is scaling like the value of Planck constant. Subelves correspond to sub-CDs. Wake-up requires a feed of metabolic energy to destroy the bound state entanglement. Self could be also created from vacuum or disappear to it in a quantum jump generating a completely new CD or annihilating it.

2. Cognitive process proceeds in a cascade like manner starting from the root of tree formed by CDs and going downwards along the tree choosing at each node some branches. For instance, understanding of a sentence would correspond to waking up of large self A representing sentence in its entirety, words its sub-selves B_i , phonemes to sub-selves C_{ij} of B_i , etc... waking-up in this order. Similarly, the act of decomposing the figure to objects and of objects to sub-objects would correspond to a temporal sequence generating selves within selves. NE would be crucial for experiencing both the whole and the parts simultaneously. Background would be the largest conscious self and objects would correspond to a sequence of selves. Selves C_{ij} and further sub-selves can be generated before generation of next C_{i+1} : this should occur in case linguistic mental image: generation of word self would be followed by the generation of syllables and phonemes and only after this would next word be generated. Time non-locality of self experience with respect to geometric and subjective time would be essential.

2.2 Cognition, Learning, And Ne At The Level Of Brain

NE is information carrier and learning is gaining information. Does this mean that learning takes place automatically in the intersection of real and p-adic worlds? Unitary U -matrix between zero energy states characterizes single step of quantum jump sequences and for negentropic states the state function reduction is not random process and in the first approximation U^N characterizes the outcome of N subsequent quantum jump so that learning process should be characterized by the iteration defined by the powers of U .

In neuroscience synaptic contacts are believed to be crucial for cognition, learning, and memory and it is interesting to try to relate this picture to the TGD based vision about conscious information and learning. How NE could be realized at the level of brain? Is it time-like, space-like, or both? Can one assign the generation of NE between neurons to the attachment of neurotransmitter to receptor? Can one relate the general quantum model of learning to the neuroscience based model of learning relying on the growth of brain cells, synaptic contacts, and synaptic plasticity?

2.2.1 The picture of the standard neuroscience about learning

It is good to summarize first the vision of standard neuroscience about the neural correlates of learning.

1. Basic notions

Synaptic transmission [J3, J9] is believed to be a key element of brain consciousness. Synaptic transmission takes place as synaptic vesicles carrying neural transmitter. Given neuron can release several transmitters. The transmitter molecules bind to the receptors at the postsynaptic cell membrane. Depending on whether this process leads to a de-polarization or hyper-polarization one speaks of excitatory or inhibitory receptors (activation potentials). Since most transmitters attach mostly to either kind of receptor, one speaks about excitatory and inhibitory transmitters although this terminology is misleading. Receptors can be classified to relatively simple ion channel receptors and more complex receptors involving second messenger proteins.

The belief is that the primary process does not involve communications with genome but if one accepts the DNA as topological quantum computer picture-in particular, on the existence of magnetic flux tubes connecting cell membrane and DNA nucleotides- the possibility that these communications are an essential element of process and that a new kind of gene expression at cell membrane level is involved. The communication to the DNA could take with light velocity if massless extremals are involved.

The synaptic strength characterizes the sensitivity of the postsynaptic neuron to the firing of the presynaptic neuron. It depends on the density of receptors and their activity as well as the total amount of neural transmitter transferred between neurons determined by the number of synaptic vesicles transmitted. This in turn depends on the size of the synaptic button. All

these parameters are affected in learning understood as a change of synaptic strengths. It must be emphasized that learning in this sense should be seen as a neural correlate for conscious (or unconscious-to-us) learning and possibly of memory. What is essential that the response of the postsynaptic neuron changes. This picture relies on the technical assumption that learning reduces to the changes of synaptic strengths. This assumption is probably an over-idealization: much more probably happens.

2. Learning at brain level

Learning in the sense as it is defined above can take place at the level of both anatomy and physiology. Learning at the level of anatomy can mean growth of new synaptic connections and of even new neurons. For instance, the growth of new neurons in hippocampus is now understood to be essential prerequisite for learning. It is believed that the information from the connections of old neurons is transferred to those of cortical neurons. This can of course happen but in TGD framework this is not necessary since the new view about time allows to interpret memory as communications with the brain of the geometric past.

Learning at the level of physiology is known as synaptic plasticity [J8] and involves several mechanisms. Synaptic plasticity means that the sensitivity of the postsynaptic neuron to the signals from presynaptic neuron can change.

1. Sensitivity means essentially the probability for the firing as a response to the firing of presynaptic neuron and this is controlled by the sign and magnitude of the activation potential and the increase of the sensitivity means a generation of stronger de-polarization or weaker hyper-polarization. Postsynaptic neuron can become more or less sensitive to the presynaptic neuron whereas presynaptic neuron can send stronger signal by increasing the number of synaptic vesicles.
2. The change of the sensitivity of the postsynaptic neuron can take place several mechanisms [J8].
 - (a) The first mechanism involves the modification of protein kinases whose function is to phosphorylate the receptor which means essentially providing it with metabolic energy. The effectiveness of the protein kinases is regulated. Second mechanism depends on second messenger neurotransmitters regulating gene transcription and regulates the levels of key proteins at synapses. Gene expression is affected in this mechanism and the effect is long-lasting.
 - (b) Third mechanism affects the number of ion channels (ion transfer between cell interior and exterior is basically responsible for the activation potential) and is involved with long term potentiation (LTP [J6]) and - depression (LTD [J5]) believed to be central mechanisms of learning memory. LTP is believed to be of central importance in hippocampus. The change of the density of receptors is one manner to achieve LPT or LTD. For so so called AMPA receptors [J1] to which glutamate binds this mechanism is well-established. Also phosphorylation and de-phosphorylation of AMPA receptors and change in the probability of glutamate release is a decisive factor.
3. The notion of Hebbian learning [J4] applies to LTP. Hebbian rules summarizes the above picture as simple mathematical rules allowing computer modelling. When pre-synaptic and postsynaptic neurons fire simultaneously, synaptic connections are affected. Weak stimulations of several pathways add up. Also temporal summation takes place if the frequency of firing is high enough. Strong stimulation of one pathway affects also other pathways. More general formulation of the rules does not require the firing of the postsynaptic neuron. For anti-Hebbian learning de-sensitization takes place. Also non-Hebbian learning is believed to take place.
4. The change of the postsynaptic action potential need not be the only outcome of learning. If this were the case, the huge number of neural transmitters and receptors inducing different responses would not be needed. The change of the sensitivity is only one aspect of learning and as its relationship to conscious learning is unclear.

2.2.2 TGD based vision about cognition and learning

In the following a brief summary about TGD inspired view concerning cognition and learning in general and at brain level is given.

1. Basic ideas

The general ideas about cognition have been also discussed but is useful to summarize them again.

1. Sub-self interpreted as a mental image is key notion. Sub-selves wake-up, fall asleep, and fuse together losing consciousness or experiencing expansion of consciousness.
2. The cascade of state function reductions can be regarded as an analysis leading to a final state in which sub-selves are either entropically or negentropically entangled systems. The latter systems can be seen as negentropic mental images resulting as sub-selves fuse together. In the case that two sub-selves are involved, the resulting mental image can be regarded as an abstraction or rule such that the state pairs appearing in the superposition correspond to the instances of the rule. If one state pair dominates then association in classical sense is in question in good approximation.
3. NE can take place between systems which belong to same or different number fields and gives rise to various kinds of conscious experiences. At least in the case that the other system is p -adic, NE should be a correlate for the conscious experience of understanding.
4. Zero energy states for brain represent rules as pairs of positive energy (initial) and negative energy (final) states. M -matrix characterizes zero energy state and defines a rule representing “laws of physics” at the level of conscious experience. Different M -matrices are orthonormal with respect to each other and in ensemble all of them appear and each of them can be also regarded as representing one particular instance of a rule.

A new element is that unitary time evolution characterized by U -matrix forces the learning to occur in the sector of state space containing zero energy states for which positive and negative energy parts of the states are negentropically entangled. U -matrix and its powers characterize the learning process. When the states are negentropically entangled, state function reduction for M -matrix is not a random process but leads to a unique state maximizing negentropy and in a good approximation the restriction of U matrix to these states codes for the evolution of M -matrix. U^N restricted in this manner characterizes the M -matrix after N quantum jumps. Therefore learning is unavoidable in the case of negentropic states and U^N at the limit of large number of quantum jumps characterizes the learning. The value of N is of course limited by the size of CD assigned to the learning system. One can of course wonder whether the unitary period is following by a return to unentangled state via the liberation of metabolic energy associated with the NE.

The powers of U define an iterative map and iterative maps are the key element of self organization and also one of the main tools of generating fractals [K26]. Quantum classical correspondence therefore suggests that 4-D fractal self-organization patterns define the space-time correlates for learning.

2. General view about learning at the level of brain

M -matrix for brain codes its view about laws of physics. In diagonal form represents pairing of initial and final states as rules $A \rightarrow B$. For instance, in fermionic degrees of freedom these rules can be interpreted as Boolean rules. More generally, the interaction as quantum associations containing superposition of instances of the associations are in question. Huge quantum superposition of rules is possible since the number of neurons large and the information storage capacity of entanglement increases exponentially with the number of neurons.

U -matrix approximated as a matrix restricted to represent unitary evolution of negentropic zero energy states assignable to brain provides the first principle description for learning as the sequence of powers U^N . In the models of associative learning learning is reduced to a local process expressible in terms of changes of the synaptic contacts. This suggests that the basic building block of U matrix is synaptic transmission. This means an analogy with the basic braiding operation of the neighboring strands represented as R -matrix defining the unitary matrix for topological quantum

computation [K12]. There is also an analogy with generalized Feynman diagrams. The incoming particles would be neurons. Synaptic transmission analogous to particle exchange between two neurons. U matrix can be regarded as a quantum superposition over all possible diagrams containing arbitrary number of synaptic transfers. Multiverse picture at neural level thus results as one might expect since macrotemporal and macroscopic quantum coherence is involved. If the situation reduces in a reasonable approximation to a description in terms of synaptic transfers one can in principle describe synaptic plasticity, LTP, and LTD and other mechanisms in terms of the basic building block of U associated with the synaptic transmission and mathematically analogous to Feynman propagator. The binding to the receptor could induce communications with genome and also the U -matrix assignable to topological quantum computations at the DNA level might be involved.

As such this picture provides only a first principle formulation for what conscious learning is and it requires a work to deduce predictions testing this vision or at least to gain understanding using this vision. A key aspect of NE is that it carries metabolic energy. This has been already proposed to provide a first principle explanation for the notion of the high energy phosphate bond crucial for the understanding of $ATP \rightarrow ADP + P_i$ process defining the key step of metabolism [K14].

Also space-like NE is possible for positive (negative) energy parts of the states. In particular, negentropic entanglement between presynaptic neuron and postsynaptic genome generated by the attachment of the transmitter to the receptor might make sense. There is temptation to assign to this connection a magnetic flux tube identified as a carrier of metabolic energy released in the process and inducing ionic currents leading to the processes affecting the synaptic strength as well as the states of neurons involved. The larger the metabolic energy release is, the more intense are the ionic currents involved and the stronger the modification is. This would provide a first principle explanation for why more effective phosphorylation of the receptor as a correlate for learning. Of course, the explanation works even without the heavy conceptual machinery if one is ready to accept the somewhat nebulous notion of high energy phosphate bond.

2.3 Ne And The Role Of Neurotransmitters

Soon after starting to develop TGD inspired theory of consciousness, I somehow ended up to an email correspondence with Gene Johnson who insistently emailed me links to abstracts about neuroscience. I read the classic Bible about brain by Kandel *et al* [J18] and tried to make sense of it in my own conceptual framework. This was of course hopeless task since I had only the notions of quantum jump and self. The feeling that something very simple -about which I do not and perhaps cannot ever have a slightest clue- must be behind this incredible complexity made the situation really frustrating. The deeper meaning of EEG, nerve pulse neurotransmitters, hormones- actually of entire brain chemistry and also biochemistry- remained a total mystery.

2.3.1 Development of ideas

After the required number of years however some concrete ideas began to emerge.

1. The notion of magnetic body with fractal onion-like structure meant a decisive step of progress. Also the hierarchy of Planck constants and dark matter as controller of visible matter in living systems emerged. The function of EEG as communication and control tool of magnetic body using biological body as a motor instrument and sensory receptor looked very natural. This led also to a proposal that there is an entire hierarchy of EEGs and their variants. After several trials a vision about nerve pulses as concomitants of quantum level communications emerged as also a vision about DNA as topological quantum computer based on the flux tubes connecting DNA nucleotides with the lipid layers of cell membrane emerged and providing a function for the intronic portions of genome as carriers of quantum computer programs [K12].
2. Also a vision about the biochemical role of dark matter evolved. In particular, phase transitions reducing Planck constant for a magnetic flux tube would induce its contraction and force biomolecules near to each other. This would explain the miracles of DNA replication,

translation, and transcription and quite generally the processes known as aggregation of proteins. The reconnection of magnetic flux tubes changing the topology of the biological Indra's net would be also a central mechanism.

3. The model of nerve pulse and the vision about living matter as a kind of dynamical Indra's net led to a first clear idea about the role of neural transmitters. Transmitters are classified to inhibitory or excitatory depending on whether they increase or reduce the magnitude of the membrane potential. This property is however a property of the receptor rather than that of the transmitter. The same transmitter can have both excitatory and inhibitory receptors although often either receptor type dominates. The proposal was that neural transmitters are associated with the ends of the links of the 4-dimensional web connecting neurons to each other. Neurotransmitter attaches to the plug defined by the receptor connecting the communication wire from presynaptic neuron to the flux tube leading to the passive portion of postsynaptic DNA strand acting as sensory receptor. This would make possible rapid communications to DNA. The corresponding active portion of DNA strand could then respond by generating an activity at the level of cell membrane. This conforms with the general idea that proteins represent only one particular outcome of the gene expression. This left open the question whether the excitatory-inhibitory dichotomy could have some deeper meaning.
4. Also it became clear the emotions and information are closely related and that peptides acting both as neurotransmitters and hormones are crucial for emotions [J12]. I proposed that emotions are "entropic" qualia. Although I realized the importance of negentropic entanglement I did not have time or I was not able to realize how far reaching this notion actually is.

2.3.2 Is genome a fractal counterpart of brain?

Fractality replaces standard reductionism in TGD Universe. An old idea inspired by p-adic length scale hypothesis is that the binary structures associated with p-adic scales $L(k) \propto 2^{k/2}$ and $L(k+2)$ define a fractal hierarchy. Brain hemispheres would represent one example of this kind of pair, lipid layers of cell membrane second one, and DNA double strand third one. Just for fun one could assume that the structure and functions of brain hemispheres have fractal analogs at the level of DNA double strand and vice versa and look what kind of questions this inspires.

1. Could the identical structures of DNA strands correspond to the anatomical similarity of right and left brain and could the functional asymmetry of the strands correspond to the lateralization of brain function? Could the genome act as the brain of cell? Could various brain areas have counterparts at the level of DNA? Could the hydrogen bonds between nucleotides serve as the counterpart of corpus callosum? Could the splitting of these bonds during transcription and replication correspond to what happens to a split brain patient?
2. Before continuing it must be made clear that the global identification of right-left dichotomy with holistic-reductionistic dichotomy is wrong. One can however consider its local variant with holism and reductionism assigned to the pairs of right and left brain areas. For instance, in contrast to the naive rule the emotional right (left) brain (amygdala) would be reductionistic (holistic, negentropic) whereas the intellectual right (left) would be holistic (reductionistic, entropic). The practical reason to the division to the entropic and negentropic pieces could relate to the metabolism. The entropic regions could provide the binding energy as a usable energy to the positive energy NE. Good is not possible without Evil! There are no winners without losers!

Right brain is specialized in spatial thinking and left brain to verbal thinking and arithmetics: the geometry-algebra division of mathematics! Right brain is not so good in motor actions as left brain as any right-handed person knows. Right brain is however better in tactile sensing: right handed persons tend to use left hand for touching objects to get an idea about their shape. Also this can be understood in holistic-reductionistic picture.

3. Apart from reflex actions almost all activities of the body seem to be controlled to a high degree by brain. Could also the activities of cell be regarded as motor actions of the genome

acting as the brain of cell receiving sensory input from the cell membrane? Could one identify the analogs of sensory areas receiving information from cell membrane, processing, and sending it to the association areas? Could the analogs associative areas be identified as intronic portions of DNA performing topological quantum computations and communicating the outcome to the higher motor areas at the intronic portions of the of the complementary strand, wherefrom they would be communicated to the primary motor areas identifiable as the regions of DNA expressing themselves either chemically (RNA and proteins), as activities generated directly at the level of cell membrane, or electromagnetically? For instance, could neurotransmitter in the receptor generate the feed of sensory input to the genome inducing the change of the membrane potential as the counterpart of motor action. Could prokaryotes without introns be analogous to brain with only primary sensory and motor areas or to mere ladder-like nervous system?

One could argue that the analogy between DNA are brain fails because second DNA strand is completely passive whereas both brain hemispheres express themselves via motor actions. This is not the case! Both DNA strand has regions expressing themselves but the transcription takes place in opposite directions. Hence DNA strands have motor and sensory areas as also brain does, and the natural guess is that primary motor areas correspond to the areas expressing themselves in terms of RNA, proteins, and possibly also as actions at the level of cell membrane. Primary sensory areas would correspond to to regions complementary to the primary motor regions.

4. What right brain sings-left brain talks metaphor could mean in this picture? Pitch-rhythm dichotomy is more technical expression for this dichotomy. Function providing local data and its Fourier transform providing global data is more abstract representation for this dichotomy and Uncertainty Principle for momentum and position relates closely to these two representations of information. This dichotomy could reflect the presence of two different natural time scales and millisecond time scale for nerve pulses and .1 second time scale for moments of sensory experience are the natural candidates.

If so, this dichotomy could directly reflect the different time scales assignable to u and d type quarks (1 millisecond) and to electron (100 ms) and reduce to the level of elementary particle physics. This dichotomy would also have fractally scaled up variants made possible by the hierarchy of Planck constants. The analog of Fourier transform would be the NE of sub-CDs (assignable to quarks) to single mental image inside electron's CD. The analog of function itself would be a collection of sub-CDs representing separate unentangled mental images assignable to individual nerve pulses in millisecond time scale. Also the topological quantum computations assigned to the intronic portions correspond to different time scales due and reflect quark-lepton dichotomy. The quarks in question could be the quarks assigned to the ends of flux tubes in the model of DNA as topological quantum computer.

5. This raises some questions. Could the gene expressions of the two strands somehow reflect this dichotomy? For instance, could the flux tube structures assignable to the amino-acid sequences correspond to the millisecond and 100 ms scales assignable to quarks and electron have the property that also the functioning of these proteins is characterized by these typical time scales? According to [I10] the time scales of protein folding vary from .1 s to 10^3 s. According to Wikipedia [I1] the typical time scale is 1 millisecond which suggests that the time scales correspond to two ranges beginning from ms and 100 ms respectively. There are also short proteins for which the folding takes place in microsecond time scales which might relate to the CD of proton.

2.3.3 What can one say about the function of neurotransmitters?

Can one say anything interesting about the function of neurotransmitters if one combines this highly speculative picture- which can be defended only by the belief on fractality as universal principle- with the idea that bound state and NE make possible the fusion of mental images.

1. Suppose that the fusion of neuronal mental images is required to build higher level mental images that we experience. Suppose that neuronal mental images involve DNA in an essential

manner. Suppose that magnetic flux tubes serve as correlates for the entanglement so that the transmission of nerve pulse from pre-synaptic neuron to post-synaptic one creates a flux tube connection between neurons possibly extending to the genome of the post-synaptic neuron. The transmitter at the end of flux tube attached to the receptor acting as a plug would build this connection to some part of DNA specialized to receive particular kind of sensory data from a particular region of cell membrane with complementary strand activating as a response a motor function inducing gene expression at cell membrane level. Gene expression as build-up of proteins would not be necessary and is also too slow for neural activities.

2. Suppose that the entanglement between neurons generated in this process is always negentropic as the interpretation as the idea about neural correlate for a conscious association suggests. One could also ask whether the neurons could entangled entropically and whether the entropic-inhibitory association could make sense. This does not lead to anything interesting and entropic entanglement between neurons should be regarded as a pathological condition. Note that neuron-neuron entanglement would be naturally time-like and in this case only NE might be meaningful.
 - (a) To gain some perspective consider the activation of cell in general by some external perturbation from the resting state to the active state (here I have learned a lot from email correspondence with Vladimir Mateev) In the resting state the proteins inside cell are passive -or rather, forced to be passive- as one might expect on basis of the general vision about homeostasis. The unfolded proteins and unfolded portions of the folded proteins are connected by hydrogen bonds to ordered water so that the folding occurring otherwise spontaneously is prevented. One can say that the cellular winter prevails. The situation is however nearly critical and if external perturbation occurs cell liberates metabolic energy melting the ice and spring comes. Also the outer surfaces of globular proteins are hydrogen bonded and when the ordered water melts, spontaneous melting of the protein takes place leading to a partial unfolding.
The resulting folded proteins and partially unfolded globular proteins interact by forming aggregates and this activity would naturally involve \hbar reducing phase transitions and flux tube reconnections. In TGD based model the mechanism of both folding and melting would be the liberation of metabolic energy destroying the hydrogen bonds and the energy for this comes from the ATP containing positive energy negentropic bond between O=s of phosphates.
 - (b) Similar situation could prevail at the cell membrane. One can imagine that cell membrane is like a particle at the bottom of a small potential well. At the other side there is a deep well representing the generation of nerve pulse and at the other side a high wall corresponding to hyper-polarization requiring energy. Both polarization and hyper-polarization are prevented by the freezing of protein activities needed to induce them. The flux tubes connecting the presynaptic neuron and receptor and possibly genome are always negentropic and their formation can as such serve as the signal leading to the partial melting of the ordered water making possible to generate action leading to either de-polarization or hyper-polarization. The signal could be just the additional metabolic energy making it possible for these transitions to occur.
 - (c) This picture does not require any communications from the receptor to the genome and in the simplest situation the resulting action could be seen as the analog of reflex action. These communications could of course be present and the negentropic entanglement could make it easier to induce de-polarization also now. Also the question whether excitatory-inhibitory dichotomy for the receptors has some deeper meaning apart from taking the neuron nearer to or farther from criticality for firing remains unanswered.

2.4 Differences Between Left And Right Brain Hemisphere

The differences between left and right brain hemisphere or lateralization of brain functions -as the more technical term states it - represent a challenge for any theory of consciousness. This difference is often stated by saying that right brain is holistic and left brain reductionistic - or more concretely - that left brain talks and right brain sings, left brain is linear and right brain parallel, or that left

brain is algebraist while right brain is geometer. The assignment of the holism-reductionism to the hemispheres as whole is probably an exaggeration. For instance, right limbic brain is specialized to negative emotions and left limbic brain to positive emotions and it is not clear whether this has anything to do with holism or reductionism. It could however be that pairs of various left and right brain regions could be characterized in terms of this dichotomy or perhaps trinity in which reductionism, holism, and their fusion are possible but that a given region of given hemisphere can favor any of these options.

2.4.1 Holism, reductionism and their fusion, entanglement, and zero energy ontology

In TGD framework the basic mechanism responsible for reductionism-holism dichotomy would be the possibility of the mental images to fuse to larger mental images. Depending on the nature of entanglement the resulting mental images are either negentropic or entropic. Entropic entanglement represents a holism as the antipode of reductionism whereas NE seems to represent a fusion of holism and reductionism. It would be tempting to assign positive emotions to the NE and negative emotions to the entropic entanglement. Both limbic hemispheres could be holistic but negentropic-entropic dichotomy would distinguish between them.

For the purposes of survival it is good to have both all these three views about reality. In politics hawks, doves and compromise makers would be a counterpart for this phenomenon. This would favor lateralization in a more general sense that a brain region in given hemisphere favours unentangled emotionally neutral mental images, negentropically fused mental images with positive emotional coloring, or entropically fused mental images with negative emotional coloring. Also metabolism could favor formation of the unpleasant entropic mental images since this liberates energy which could be stored in metabolic entanglement as a metabolic energy. Interestingly, it has been proposed that the simultaneous presence of holism and reductionism could explain the amazing mental feats of idiot savants. The irony is that these persons are usually unable to describe their experiences using language, which brings in mind the reports of meditators telling that it is impossible to tell anything about enlightenment experience using language. Maybe language relates crucially both to the ability to decompose the mental images to smaller pieces and to form entropically entangled wholes of them.

I might be self-contradictory here. On one hand, I have proposed that the feats of idiot savants are possible because they do not conceptualize and in this manner replace reality with the names of the objects of the reality: something extremely economical if one counts bits. On the other hand, I am proposing that the formation of concepts corresponds to the NE. It seems that I should distinguish between two kinds of conceptualizations: the NE without language on one hand achieved in meditative practices and the combination of both entropically entangled and non-entangled representations making possible language but losing the insight of genius.

Zero energy ontology suggests a quantitative formulation of this vision based on the observation that the time scale of electron's CD corresponds to the 1 second time scale defining fundamental biorhythm whereas millisecond time scale defining the fundamental time scale of nerve pulse activity could relate closely to the time scale of CDs assignable to u and d quarks predicted to play a key role in quantum information processing in the model of DNA as topological quantum computer. There are also shorter time scales, in particular the time scales assignable to proton which can be estimated to be of order 10^{-7} seconds. Also p-adically scaled up variants of these time scales are possible as well as zooming of these time scales at the pages of the Big Book defining generalized imbedding space and partially labeled by the values of Planck constant. The first guess is that quark and lepton time scales are behind the reductionism-holism division. Holism would mean temporal binding of the mental images assignable to nerve pulse patterns and characterized by millisecond time scale to negentropic (or possibly entropic) sub-selves characterized by 1 second time scales. Quark like sub-CDs of electronic CDs would serve as imbedding space correlates for these mental images.

2.4.2 Objection against simplistic view about lateralization

The hypothesis that right brain is more holistic than left brain can be tested and a considerable support for the hypothesis have been found. There is however a rather paradoxical experimental result challenging the hypothesis in its simplest form and suggesting that the roles of various

processing levels of brain hemispheres in the specialization to geometric shapes and linguistic symbols can vary. In [J17] there is report about two experimental situations testing right-left differences.

1. Subject persons saw figure S consisting of smaller figure F: s. On basis of neural firing left brain seemed to recognize smaller F: s whereas right brain seemed to recognize the entire figure S: just as expected.
2. For control purposes figure S consisting of small F: s was replaced with a figure of anchor consisting of small cups. What happened was that left brain recognized the anchor and right brain recognized the cups! Also firing patterns were essentially the same! It was conjectured that the smallness of cups -smaller than letter F: s- might have something to do with the unexpected result.

Apparently the replacement of letters with geometric shapes means that the roles of brain hemispheres changed. This suggests that the naive vision about roles of hemispheres must be replaced with something more complex in which one has scale hierarchy of levels such that each level has its own specialization.

1. Suppose first that at the lowest level of the hierarchy the left hemisphere is better in recognizing letters than familiar shapes and right hemisphere better in recognizing familiar geometric shapes than letters.
2. The subject persons are asked to concentrate on either the entire figure or details which repeat themselves. This raises the question whether a single detail becomes actually the whole since the attention is directed to details. If this is the case, the first assumption would explain why right brain hemisphere fires as cup is recognized. Same applies to the left hemisphere in the case of letter F.
3. When the figure as a whole must be recognized, the recognizing hemisphere seems to be the one for which the recognition should be more difficult! The hierarchy of CDs allows to consider the possibility that there is a fractal hierarchy of levels corresponding to different size scales for the structures appearing in the figure. The very fact that subject person is conscious about the existence of smaller details means that smallest structures are mapped to the first level of the hierarchy so that in both cases the figure as a whole would be mapped to the second level of the hierarchy. If one takes the experimental result at a face value, letters should be more familiar to the right hemisphere and geometric shapes of everyday objects to the left hemisphere at the second level of the hierarchy.
4. That the roles of brain hemispheres in lateralization depend on the level of the hierarchy might have an explanation in terms of basic information processing involving communications between hemispheres. Maybe there is a mapping from the first level of hierarchy of a given hemisphere to the second level of hierarchy at the opposite hemisphere and so on. At higher levels of the hierarchy the hemispheres would perceive each others visual percepts. Right hemisphere at the n : th level would receive sensory signals from $n-1$: th level of left brain and vice versa. In this kind of situation the maximal effectiveness of the information processing would be achieved if these two ladders rather than hemispheres have similar specializations.

2.4.3 Some examples

This framework explains various aspects of holism-reductionism dichotomy when given pair of brain regions is considered but it is not meant to apply to brain hemispheres as a single pair.

1. Linear-parallel dichotomy suggests that in a given time scale left hemisphere corresponds to large number of un-entangled sub-selves whereas right hemisphere would correspond to a larger number of entangled sub-selves with entropic (at least in case of limbic brain) or NE. For instance, the unentangled sub-selves can correspond to letters of written text at left hemisphere. At right hemisphere they could correspond to objects of everyday life or even understood words of written text with mental images representing letters entangling

negentropically in time direction to form a single mental image. Also much smaller details such as edges and lines of figure having no direct meaning are certainly involved.

Left brain seems to be skilled in forming mental images about structures consisting of well defined components whereas right brain can grasp the general shape and size of the structure (note however the previous example in conflict with this belief). This could be understood if left brain represents structures linguistically as associative linear structures consisting of parts represented as sub-selves. Thus a structure could be realized as a reverberating neural circuit in which sub-selves representing parts of the structure keep each other awake.

2. Right hemisphere is also claimed to be less analytic. It might be that also this might hold true only for the right-left-right-.. information processing hierarchy when compared with left-right-left... hierarchy beginning from left brain hemisphere. Certainly the entanglement of mental images would explain this.
3. That left brain talks whereas right brain (almost) sings is more than a loose metaphor. It is known that people who have left brain injury and cannot talk can sometimes express themselves by singing. Linear-parallel dichotomy would suggest that left brain is specialized to subjecto-temporal sequences of parallel small-sized mental images of short duration (say words of speech): this would correspond rhythm and other temporally local aspects of music which dominate in speech. Right brain is specialized to large selves formed by the fusion of parallel sub-selves formed by, say, separate notes of music which can last long time and have no linguistic content. These mental images should carry conscious information about non-local aspect such as pitch of the sound. Although the notes of song are heard one in time, they would continue to live in right brain as parallel mental images and make possible to experience the melody as sad or joyful or to remember the key of the music piece.
4. The poor temporal and spatial resolution assigned to the right hemisphere can be seen as a price paid for the holism of entanglement. Again one must however remember that a scale hierarchy might be involved.
5. The claim that right brain is more emotional should be taken with a caution. It seems better to say that the right limbic brain is dominated by negative emotions and left limbic brain by positive ones. The interpretation would be in terms of entropic *resp.* negentropic entanglement: in this sense left brain would have higher emotional intelligence. On the other hand, right brain is claimed to have better skills in recognizing and expressing emotions. This is not in conflict with the fact that left brain hemisphere is the happier hemisphere. These skills could be understood as a more holistic expression of emotions and their perception, and might also relate to the ability of the right hemisphere to generate negentropic entanglement with other brains.

2.4.4 Dr. P. and twins who saw primeness

Oliver Sack's book "The man who mistook his wife for a hat" [J23] contains fascinating stories about those aspects of brain and consciousness which are more or less mysterious from the view point of neuroscience. There are two stories which relate very closely to reductionism-holism tension of conscious experiencing.

The first story is about Dr. P. who suffered visual agnosia and could not recognize concrete objects, say faces unless some nonvisual association was involved. He could however recognize abstract symbols or objects containing some symbolic details making possible the recognition (he recognized Einstein's face, which has indeed become a symbol of wisdom!). Sacks tells about how his patient tried to recognize glove. "A curved shaped containing five small bags" was his abstract analysis: he could not identify the glove as a glove unless he got it in his hand! He could however define glove as an abstract geometric shape allowing simple linguistic description. Dr. P. could identify abstract shapes and symbols like letters and geometric objects but could not recognize real world objects. Amazingly, Dr. P. used musical associations as a manner to cope with the complexities of everyday life. He singed through all his everyday activities and lost control totally if this was for some reason not possible. He could also continue teaching of this music class. For

instance, he could recognize his music students only when they moved by recognizing their “body music”.

As discussed, reductionism-holism duality provides the deep reason for why we have two brain lobes. This allows to understand what might be possibly involved with Dr. P: s case. Dr. P: s right visual areas had been damaged and he could not recognize faces and concrete objects of the visual field. Left visual areas were in good condition and he could identify abstract objects. Other than visual areas were still in good condition in both hemispheres and he could perform recognition using musical associations, associations created by smells, etc... Sacks notices also a deep analogy with Dr. P.: s case and neuroscience. Expressing rather freely what Luria said, entire neuroscience up to seventies provided analytic description of left brain about left brain. It had indeed turned out very difficult to assign any easily identifiable cognitive dysfunctions with localized right brain injuries and Luria’s opinion was that this necessitated completely different approach which he called “romantic” (stories of right brain about both right and left brain!).

In fact, one can formulate new kind of Uncertainty Principle, perhaps it might be called Uncertainty Principle of cognition. Same mental image cannot be both holistic and reductionistic simultaneously. The combination of reductionistic and holistic descriptions (and all possible intermediate descriptions combining parts to “sub-wholes” in various manners) to single description is impossible even in principle! Science and Art as descriptions of the world are very much like mutually incompatible observables of Uncertainty Principle! The obvious reaction of the alert reader is that NE might allow to achieve both reductionism and holism simultaneously. Maybe this is the case but in this case there is no manner to communicate the mental using language if the proposed interpretation is correct.

Sacks tells also about twins, John and Michael, who had mysterious ability to “see” large numbers. For instance, matchbox was dropped from the table and its contents were spread along the floor. Both twins shouted immediately “111!”. Then John mumbled “37”, Michael repeated it and John said “37” third time. Obviously this was their cognitive representation for the decomposition $111=3 \times 37$ of number 111 to a product of primes!

How John and Michael did these numerical feats? The first thing to notice is that twins had intelligence quotient of about 60 and could not perform even simplest arithmetical operations. They did not even understand what the concepts of prime and decomposition into prime factors mean conceptually. They however experienced primes as especially interesting numbers and even played a game in which they invented new primes. One can safely assume that they did not consciously calculate the decomposition of number 111 to a product of primes. When asked how they were able to tell the number of matches, they told that they “saw” it. In fact, their eyes moved in strange manner always when they were performing numerical tasks and stopped when the solution was found. Also the decomposition of 111 to a product of 3 primes “37” seemed to occur completely spontaneously “in front of their eyes”.

The mysterious ability of twins is not a mere curiosity but could provide a crucial clue to the problem of understanding of how numbers are realized as mental images. Indeed, also ordinary human beings are able to experience directly “N-ness”, when the size of N is small. A sensory memory associating the visual mental image with the verbal representations of “N” could be in question. This association resembles synesthetic associations, which are also completely automatic.

Thus the problem transforms to a more general question “How integers are experienced directly?”.

1. In TGD framework the answer to the question is obvious. Experiencing of “N-ness” means experiencing “N” separate objects as a single whole and corresponds quantum physically to the generation of NE between the cognitive representatives of individual objects. If the resulting mental image associates automatically with a linguistic expression for “N-ness”, say $N = 5 \leftrightarrow \text{five}$, reportable recognition of “N-ness” occurs. 7 ± 2 law suggests that this entanglement and association usually occurs only for maximal number of objects not larger than $N = 7 \pm 2$. In case of a numerical genius this number seems to be drastically higher. The generation of this entanglement should be spontaneous self-organization process in either brain hemisphere and entangled objects could correspond to separate neuron groups or neurons.
2. The decomposition of integer $N = N_1 \times N_2$ to a product of integers must in this picture correspond to the spontaneous formation of identical “sub-wholes”. This process must be

a quantum self-organization process. It could favour the decomposition of $N = N_1 \times N_2$ objects to N_1 “sub-wholes” consisting of N_2 entangled basic objects or decomposition of N_2 sub-wholes consisting of N_1 basic objects or something else depending on factors of N . This kind of final states of self-organization are natural since they are very symmetrical consisting of a repetition of an identical basic unit. This kind of self-organization patterns are analogous to the lattice-like self-organization patterns of Benard flow.

3. NMP [K20] could be involved in the following manner. Suppose that the perception of the number of N objects generates in brain an ensemble consisting of N mental images, which entangle negentropically. If so, then the simplest expectation is that entanglement probabilities are proportional to $1/N$ and the number theoretical entanglement entropy is large only for p-adic primes dividing N . The prime divisor of N giving rise to the largest number theoretic negentropy would determine the p-adicity involved and this could correspond to a perception about the decomposition of the visual representation of N to N/p pieces.

The model also explains the ability of twins to see whether a given number is prime or not. Primes are stable against decomposition into sub-wholes and are therefore “elementary particles of cognition”. Hence primeness is a “visible” property: primes are numerical mental images stable against decay to a set of identical numerical mental images. Note that this dynamical process breaks the symmetry between the factors of integer. This clearly occurred in $111 = 3 \times 37$ example. Twins did not “see” “3”: they saw only some 37’s and did not explicitly tell that there were precisely three 37: s!

In [K3] a more concrete model for how real space-time sheets could represent integers and their prime factorization by their effectively p-adic topology, is discussed.

2.5 Music And Consciousness

Music experience provides an interesting testing ground for several assumptions of quantum TGD and TGD inspired theory of consciousness. The notion of self is especially interesting in this respect.

2.5.1 Some aspects of music experience

It is good to list first some elementary characteristics of music experience that the model should be able to explain. Both rhythmic aspects and pitch of the sound are important. Rhythmic aspects correspond to time domain representation for the intensity of sound carrying local information about sound wave whereas pitch carries global information. The relationship between these two elements of music is like that of function and its Fourier transform. Harmony enters the game when several frequencies are present.

1. Rhythm

There are two basic types of views about rhythm, additive and divisive, and they correspond to the multiplication and sum as basic arithmetic operations.

1. In western music rhythm corresponds to a division of longer periods of time divided into smaller rhythmic units. Rhythm is basically a clock and rhythm is essentially a decomposition of integer to a product of integers defining the rhythmic unit and their number. Classical western music is relatively simple rhythmically (consider only the music of Bach). In the music of Chopin tempo rubato makes the duration of the basic rhythmic unit and of its basic structural elements dynamical but rhythms are still relatively simple although simultaneous $3/4$ and $3/8+3/8$ appears often. In jazz and various forms of popular music rhythms tend to be highly clocklike but are very complex.
2. In Indian music for instance, rhythms are additive and larger periods of time are constructed from smaller rhythmic units added to the end of the previous unit. This division corresponds to addition rather than multiplication algebraically. Also intermediate forms can appear and do so often in folk music (say folk music of Greece, Balkan, and Spain). For instance, one can have the sum of $3/4+3/8+3/8$ as a repeating rhythmic unit. In flamenco form known

as Bulerias [J2] the basic rhythmic unit consists of 12 beats and the collective performance creates a very complex and emotionally catching rhythm, which is almost impossible to analyze to pieces. It is easy to believe the claim that artists often fall in trance during the flamenco sessions.

2. Pitch

Pitch can be identified as the fundamental frequency of note. Pure sine wave is aesthetically unpleasing and harmonics are always present and characterize the music instrument. Not only frequencies but also phase relationships between them are important. For instance, they distinguish between the phonemes of spoken language and in the case of singing this brings in an important additional element not so important for non-electronic instrumental music. Furthermore, melody is never a mere sequence of precisely defined frequencies. For instance, slow modulations of the pitch reducing mathematically to a superposition of closely separated frequencies and glissandos have emotional affect.

The model of music experience should explain also the following aspects related to pitch understood as fundamental frequency.

1. Octaves of the fundamental are experienced as equivalent. The presence of higher harmonics is needed to make pure sinus wave a musical note. Higher harmonics determine the character of the pitch characterizing the music instrument.
2. There exists a large number of different scales to which one assigns attributes like diatonic, minor, chromatic, whole tone, pentatonic, diminished... All these scales have quite specific emotional coloring and they characterize different music styles. The minimum frequency interval corresponds to a minimal scaling of the frequency and depends on music style. Western classical music uses semitone as the basic unit corresponding to the scaling $2^{1/12}$ in equally tempered scale but also microintervals are used and the only limitation comes from the ability to discriminate between different frequencies. The scales have special notes such as tonic, supertonic, mediant, subdominant, dominant, submediant, subtonic with special roles in harmony. For instance, listener is often able to remember the basic scales even if the tonic of the scale has suffered several modulations during the music piece. Deviations from basic scale have important emotional effects (say in the case of minor scale).
3. Ancient mathematicians believed that the presence of rational multiples of fundamental frequencies are essential for harmony. It is possible to construct the basic scales involving only rational multiples of the fundamental in terms of selected harmonics. For instance, Pythagorean construction uses only powers of $3/2$ and octaves to construct the basic scale (C, G, D, A, E, H, ...). Although the pitch is distinguished only within a finite resolution and equally tempered 12-note scale uses only powers of $2^{1/12}$ of the fundamental, rational multiples of the fundamental might relate deeply to the basic physics of cognition and to the frequencies generated in brain as opposed to those used to produce the music.
4. The expectation of an engineer is that the transposition of the scale should not effect on the music experience and one could think that it could be done in a continuous manner. Many composers, for instances Sibelius, experienced different modes differently and as synesthetes assigned to them different visual associations. Many people are able to recognize the ratios of notes but there is also the much rare phenomenon of absolute ear meaning that subject person is able to tell the pitch of the note directly. A synesthesia like phenomenon is probably in question.
5. An interesting question the notion of absolute scale could make sense to some degree? The fundamental frequency of sound producing organs is 10 Hz and the region of audible frequencies begins at 20 Hz and consists of approximately 10 octaves. kHz frequency is the resonance frequency of head sized object and at this frequency the mechanism allowing to deduce the direction of sound source changes. The biological basis for this would be that 10 Hz and 1 kHz define fundamental biorhythms. The quantum physical basis for this could relate to the p-adic length scale hypothesis predicting that 10 Hz and 1280 Hz could correspond CDs of electron and quarks. To get a contact with concretia note that soprano C corresponds to

1046.50 Hz. Also the cyclotron frequencies assignable to various biologically important ions in endogenic magnetic fields could define preferred scales. The A above middle C corresponds by convention to 440 Hz, which is integer multiple of 10 Hz but by pure convention and fifth octave of 8.175 Hz which is not too far from the lowest Schumann resonance. An interesting question is whether the transposition to a scale for which the fundamental is simple rational multiple of 10 Hz or lowest Schumann resonance might have some specific emotional effect.

3. *Harmony and other collective aspects of music*

Harmony relates closely to the interaction of different frequencies and is therefore one particular collective aspect of music experience.

In the terminology of physicists, harmony is a phenomenon of many particle physics with particles replaced notes of the scale and many-particle states with chords. Depending on the ratios of the frequencies certain chords are aesthetically pleasing and emotionally significant and there are also principles governing aesthetically pleasing chord progressions. Harmony might be seen as the vertical aspect of the music whereas melody would correspond to horizontal one. Dissonance is the opposite of harmony and tritonus was forbidden in the early western music but is nowadays used to create tension. Polyphony -say in Bach's music- and simple chords used to accompany singing represent two opposite views about harmony. Chopin's music has especially rich harmonies and emotional expressive power.

While listening music one typically selects some instrument as figure and the rest as a background. In romantic piano concertos the competition between the solist and orchestra about the attention of the listener creates the basic tension. In polyphonic music one must also select the tone progression to which attention is directed and it is difficult -perhaps even impossible- to simultaneously grasp the separate tone progressions. Same applies to other elements of music.

2.5.2 Zero energy ontology, hierarchy of Planck constants, and number theoretic physics

The number theoretic vision brings interesting new physics elements which might help to understand music experience.

1. The hierarchy of selves has as an imbedding space correlate the hierarchy of CD is basic prediction. p-Adic length scale hypothesis suggests that quantization of size scales of CDs as octaves and the question is whether this relates directly to the preferred role of octaves in music experience. The time scales of CDs define preferred fundamental frequencies coming as octaves and the hierarchy of Planck constants defines scaled variants of these as rational or integer multiples (depending on generalization of the imbedding space).
2. The question is whether these fundamental frequencies also define fundamental keys so that music experience would depend on absolute frequency scale. Even if CDs define fundamental keys, the frequency scale associated with sub-CD as experienced in the rest system of CD can be scaled continuously by performing a Lorentz boost for CD. Even glissando could be achieved for CD by performing to the sub-CD a Lorentz boost continuously and leaving the other tip of CD invariant. The boost would be the hyperbolic analog of an ordinary rotation and act like acceleration from rest to constant velocity inside sub-CD. If one takes this picture seriously also Lorentz boosts would be important part of the representation of music at the level of magnetic body (presumably using MEs). Quantum TGD proper suggests the quantization of these boosts.
3. Number theoretic vision predicts an infinite number of algebraic extensions of rationals inducing those of p-adic numbers -in particular those corresponding to roots of unity. In the p-adic context the proper representation of sine waves requires the introduction of these algebraic extensions and the prediction is that rational multiples of the fundamental frequencies assignable to p-adic length scales should have a special role from the point of view of cognition. In fact, the algebraic extensions are now the correlate for the evolution and define a hierarchy of adelic physics predicting the existence of preferred p-adic primes and when combined with NMP also a generalization of p-adic length scale hypothesis [K34].

This might justify the belief that the notes of the scale should be expressible in the optimal situation as rational multiples of the fundamental note. The cognitive representation of the music in the intersection of real and p-adic worlds should map the physical frequencies or rather the sine waves at a discrete set of time values to their p-adic counterparts. One has to deal with phase factors defined by plane waves $\exp(ift_n)$ at discrete set of points t_n such that the exponent equals to $\exp(i2\pi m/N)$ and belongs to the algebraic extension. The harmonics of f obviously satisfy the same condition. The representation of pitch in terms of algebraic extensions of rationals requires that the corresponding partonic 2-surfaces correspond to complex enough algebraic extensions of rationals containing high enough roots of unity. The modulation of the pitch as superposition of two nearby rational frequencies could be possible without leaving this framework.

4. One can consider also different but not exclusive explanation for why scales define preferred collections of frequencies. Pythagorean scale involves rational multiples of fundamental obtained as powers of $3/2$ and 2 so that the frequencies involved correspond to rationals of form $3^m 2^n$ for which only 3-adic and 2-adic norms differ from one. Small-p p-adicity associated with $p = 2$ and $p = 3$ could select the preferred frequencies.

2.5.3 Why octaves are experienced similarly?

The model should explain the basic features of music experience. There are many interesting questions related to this. One of the most important is why frequencies which are 2^k - multiples of the fundamental frequency, notes differing by octaves, are experienced as identical notes.

1. *p-Adic length scale hypothesis, zero energy ontology, and octaves*

Thus the phenomenon of octaves could relate to the p-adic length scale hypothesis, which implies that physically preferred p-adic primes correspond to primes near prime power powers of two. For instance, this implies that the massless extremals (MEs) associated with physically important p-adic primes have fundamental frequencies which are octaves of each other. Therefore a classical resonance via the formation of join along boundaries bonds/flux tubes becomes possible and real space-time sheets corresponding to preferred p-adic primes can form larger resonant structures. This universal resonance could explain why octaves are experienced similarly. The problem of this argument was that primary p-adic time scales would come as half octaves instead of octaves.

Octaves seem to have much deeper significance than I thought originally and seem to emerge at the level of fundamental formulation of quantum TGD rather than characterizing only a very special kind of sensory experience. In the recent formulation of quantum TGD using zero energy ontology [K9, K8] one uses zero energy states which have their positive and negative energy parts at the light-like boundaries of causal diamonds consisting of future and past directed light-cones.

Physics as a generalized number theory vision, in particular the assumption that real physics and various p-adic physics result as algebraic completions of rational physics, motivates the hypothesis that the temporal distance T between the tips of the causal diamond is quantized and corresponds to powers of 2 using time scale defined by CP_2 size as a basic unit. This assumption allows to deduce p-adic length scale hypothesis ($p \simeq 2^k$, k integer), and to identify T as a secondary p-adic time scale. For electron this time scale is .1 seconds and corresponds to the fundamental 10 Hz biorhythm. For non-standard values of Planck constant T is scaled by a factor \hbar/\hbar_0 . Thus octaves become a key element of fundamental physics. One can say that causal diamonds as space-time correlates of self appear naturally as octaves. Also rational multiples of fundamental frequency emerge via the hierarchy of Planck constants: in principle all rational scalings of the basic hierarchy are allowed.

2. *Is sensory experience 2-adic in some sense?*

A stronger hypothesis for the phenomenon of octaves is that cognitive music selves are 2-adic or that real music selves can transform easily to 2-adic selves. One might even consider the possibility that the phenomenon is much more general. Music metaphor has indeed turned out to be of crucial importance for the theory of qualia. Thus music metaphor could reflect the underlying 2-adicity of the sensory experience (at some level of self hierarchy). Perhaps at least some aspects of our experience result from a mimicry of the lowest level of the p-adic self-hierarchy. Taking 2-adicity

seriously, one is forced to ask for the possible consequences of 2-adicity. For instance, could it be that at the level of primary qualia the intensity of sensation as function of stimulus depends on the 2-adic norm of the 2-adic counterpart of the stimulus and is thus a piecewise constant function if sensory input?

An observation supporting this speculation is following. When over-learning occurs in tasks involving temporal discrimination, the intensity of sensation as a function of stimulus deviates from smooth logarithmic form in small scales by becoming piecewise continuous function [J16] such that the plateaus, where response remains constant are octaves of each other.

This observation suggests a generalization inspired by 2-adic version of music metaphor. Primary quale has a multiple of cyclotron frequency as its correlate and, being integer valued, is essentially 2-based logarithm of the 2-adic norm for the 2-adic counterpart of the intensity of the sensory input. Hence the increase of intensity of the sensory input by octave correspond to a jump-wise replacement of the n : th harmonic by $n + 1$: th one and should be seen in EEG. Our experience usually corresponds to the average over a large number of this kind of primary experiences so that underlying 2-adicity is smoothed out. In case of over-learning or neurons involved act unisono and the underlying 2-adicity is not masked anymore.

At the level of MEs this would mean generation of higher harmonic when the number of nerve pulses per unit of time achieves threshold value allowing the amplification of corresponding frequency by the mechanism discussed already earlier. This certainly would mean that cognition is an important part of music experience. The strongest assumption is that the real note selves are able to transform to 2-adic selves by a phase transition changing local topology from real to 2-adic. Note however that p-adic length scale hypothesis might be enough.

2.5.4 Does harmonic complexity reduce to 3-adicity?

An interesting question relates to the conditions guaranteeing that a chord is experienced as harmonious in the Pythagorean sense [J7]. Pythagorean tuning is based on the notion of perfect fifths identified as scalings by $3/2$ producing the sequence C, G, D, A, E, .. In this tuning major-C scale corresponds to ratios $C = 1/1, D = 9/8, E = 81/64, F = 4/3, G = 3/2, A = 27/16, B = 243/128, C = 2/1$. E_b and $F_{\#}$ correspond to ratios $2^5/3^3$ and $3^6/2^9$. All notes are expressible as powers of two and three. Since the multiplication of any note by a power of two does not affect the harmony it should be to drop the powers of two from the integers characterizing the notes in the ratio of three notes. For instance, C-E-G reduces $3 : 3^4 : 1, C - E_b - G$ to $3^4 : 1 : 3^3$, and tritonus $C - E_b - F_{\#}$ to $3^9 : 1 : 3^3$. The problem of Pythagorean tuning is that one cannot represent 2 as an exact integer power of $3/2$ and the scalings give infinite number of tones. If the construction starts from G_b then $F_{\#}$ and G_b correspond to frequencies, which are not quite identical in Pythagorean tuning. One could make compromise by introducing the geometric mean of $F_{\#}$ and G_b but this would bring in $\sqrt{3}$ and would force to leave the world of pure rationals. For string instruments and electronic instruments the Pythagorean tuning is practical but for instruments like piano the transposition of the scale is impossible.

One should be able to characterize a given chord harmonically by a function $F(a, b, c)$, which is symmetric under the permutations of the reduced pitches a, b and c obtained by dropping powers of two and is invariant under over all scaling of the reduce frequencies. The elementary symmetric functions $F(a, b, c) = [a^2(b + c) + b^2(a + c) + c^2(a + b)]/abc$ and $G(a, b, c) = [a^3 + b^3 + c^3]/abc$ are the simplest functions of this kind. Either of these functions or their product or ratio could be considered as a measure for the harmonic complexity. The value of the denominator abc equals to 3^n , $n = 3, 7, 12$ in the cases considered. The numerator has in all cases 3-adic norm equal to one for both F and G . This suggests that the 3-based logarithm of the 3-adic norm $1/|abc|_3 = |F|_3 = |G|_3$ having the values 3, 7, and 12 for C-major, C-minor, and tritonus could serve as the measure for the complexity. It is indeed smallest for major and largest for tritonus. 3-adic norm for the product $1/a_1 a_2 \dots a_n$ of n notes of the chord defines a measure of complexity in more general case. A good guess is that the 3-adic norms of the elementary symmetric functions give rise to the same measure.

For the chords C-E-G, F-A-C, and G-H-D appearing as basic chords in C- major scale the values of the harmonic measure are 3, 2, and 8. This means that the basic chords are not harmonically equivalent in Pythagorean system whereas in equally tempered system they would be. One might think that this explains why the tonic is remembered. The anomalously low value for F-A-C

relates to the fact that it is only tone for which the power of 3 is negative. Situation changes of F is identified as a minimal power of 3 giving F equivalent with Pythagorean F within the resolution of ear to pitch which is about $|\Delta f/f| = 4.3$ per cent. $F = 3^5/2^8$ gives $|\Delta f/f| = 4.8$ per cent. This F would give for F-A-C the harmonic measure 8 which equals to that for G. This looks more reasonable than the purely Pythagorean value. This definition would also allow to find a unique choice of powers of three for 12-chord system. For instance, $F_{\#}$ is favored over G_b since it corresponds to a positive power of 3.

The ability to express the notes of scale as powers of $3/2$ by projecting the outcome to the basic octave suggests strongly that 3-adicity is an key element of music experience. Years after writing the first version of this text, I received an interesting email from Jose Diez Faixat giving a link to his blog (<http://tinyurl.com/ycesc5mq>). The title of the article in the blog is “Bye-bye Darwin” and tells something about his proposal. The sub-title “The Hidden rhythm of evolution” tells more. Darwinian view is that evolution is random and evolutionary pressures select the randomly produced mutations. Rhythm does not fit with this picture. Faixat published 1993 the first article about his observations in the journal World Futures Vol. 36, pp. 31-56, edited by Ervin Lazlo with the title “A hypothesis on the rhythm of becoming” [I8, I9].

Thus it seems that 3-adicity might be fundamental not only for music experience but for biology. This conforms also with the generalization of p-adic length scale hypothesis implied by the weak form of NMP [K34] that primes near powers of primes are favoured by NMP. p-Adic length scale hypothesis corresponds to $p = 2$ and Faixat’s findings and music experience support $p = 3$.

2.5.5 The notion of self and music

The music experience allows also to test the ideas related to the notion of self.

1. Summation hypothesis states that self is a sum of abstracted experiences of sub-selves and thus representing kind of averages about the experiences of sub-sub-selves.
 - (a) The conscious experience induced by music decomposes in a clear manner to basic elements identifiable as sub-selves. For instance, melody and more generally various tone progressions could define such sub-selves and the experiences of these sub-selves would sum up to music experience. In the same manner rhythmic patterns define their own sub-selves. Therefore it might make sense to speak about “frequency sub-selves” and “rhythm sub-selves”.
 - (b) At space-time level the magnetic body and massless extremals (MEs) are the natural candidate for the representation of “frequency sub-selves”. One can say that MEs provide a universal music instrument at the level of magnetic body since they allow arbitrary superposition of collinear waves proceeding in the same direction which is non-dispersive (shape of the pulse is preserved) so that arbitrary harmonics are possible for a ME with fixed length. Maybe the temporal duration of sub-selves assignable to MEs is what distinguishes between these representations.
 - (c) A collection of sub-selves associated with ME at precisely defined periodically appearing positions could define rhythm whereas frequency selves would correspond to MEs with relatively long temporal duration. Interpreting MEs in terms of communications to the magnetic body, one expects that the rhythm automatically generates short-lasting MEs communication the pulses defining the rhythm to the magnetic body whereas pitch corresponds to long lasting MEs.
 - (d) This picture challenges the assumption that the mental images created during music experience are localized to brain. Rather, MEs and magnetic body would be the carriers of the mental images. Maybe one could say that nerve pulse patterns induce these MEs. In left hemisphere nerve pulse patterns induced by the beats of rhythm and having a total duration considerably below 1 second would send single ME to the magnetic body. In right hemisphere the pulse patterns would integrate to single ME having duration of the note.
2. The hypothesis that entanglement creates wholes from parts and that there are three cognitive modes corresponding to reductionistic and holistic cognition and their hybrid based on negentropic entanglement is of special interest in the context of music experience.

- (a) Even admitting the dangers of naive right-left thinking it would seem natural to assign the rhythmic aspects of the music to the reductionistic regions of brain and various aspects related to pitch to the right brain hemisphere. At least in the latter case MEs are highly suggestive as a fundamental representation of music at the level of magnetic body. Perhaps music experience actually involves in a very essential manner also magnetic body. That “eastern” music favors additive instead of divisive rhythm could be understood as higher right brain dominance. The extremely mechanical rhythms characterizing the popular music today, the lack of melodic aspects, and the use of the volume of music as the basic means to induce emotional effect, could in turn be interpreted in terms of extreme left brain dominance.
 - (b) Music can have a strong emotional effects and this allows to test the hypothesis that the character of entanglement correlates with the emotional color. Maybe just the fact that these emotions are enjoyable irrespective of whether they are sad or joyful and have an undeniable healing effect can be interpreted in terms of the presence of the NE. For instance, the ability of good music to generate vibrations in spine could relate to this negentropic aspects. Music as purely intellectual experience could induce essentially an analysis of what was heard based on the use of holistic-reductionistic dichotomy. Chopin’s music has especially strong healing effect. Tempo rubato might reflect the profound integration of rhythmic aspects, melodic, and harmonic to single organic whole both at the level of representation and music experience.
3. The model of subjective memory and the new view about time might be relevant for the understanding of how the basic key of the music piece can be remembered. If conscious experience for a given self is about the space-time region defined by corresponding CD, one could understand how Mozart was able to experience the entire composition as a single whole. If the music piece defines in the ideal case the fundamental CD inside which the sub-selves representing the elements of the music piece reside, this CD could also define the fundamental “key” and would be more or less sensorily experienced and need not even to be remembered. This would explain why the return to the original key in classical is so important to relieve the tension created by modulations.

2.5.6 Harmony and self-organization

The phenomenon of harmony should be somehow related to quantum self-organization: perhaps the often used metaphor of harmonious co-existence could be turned around. Various notes correspond to sub-selves in the population of sub-selves and it might be that self-organization favours simultaneous conscious existence of sub-selves corresponding to subsets of frequencies defining basic chords. One could even consider some kind of co-operation between the frequency selves belonging to same basic chord.

The simplest model for the phenomenon of harmony relies on the identification of the chords as “chord selves” formed by entangled “note selves” consisting of negentropically entangled “frequency selves”. The listener is self having as sub-selves (mental images) note selves and chord selves which correspond to the same level of the self hierarchy. The entanglement between note selves could occur even at the level of ear between the mind-like space-time sheets sensitive to various frequencies. Topologically it would correspond to the formation of magnetic flux tubes between corresponding partonic 2-surfaces. The ability of the “note selves” of the chord to have stable flux tube bonds between themselves should depend crucially on the fact that the frequencies of the notes of the basic chords have simple rational ratios so that the oscillations involved are commensurate and match together. Hence a resonance phenomenon in spirit of classical physics involving rational ratios of frequencies would be in question. During listening the chord self continually decomposes into sub-selves when listener consciously concentrates attention to some notes in the chord.

The ability of the music to occasionally create thrills in spine could correspond to whole-body consciousness in unusually large length scale. Note that this scale could correspond also to the secondary time length scale assignable to CD. It presumably involves a resonant fusion of also other than note sub-selves to larger negentropic sub-selves by the formation of stable flux tubes identifiable as magnetic flux tubes. The ability of certain sounds (“Om”) to promote the emergence of whole-body consciousness could be due to the ability to very effectively generate negentropic

entanglement direction. Perhaps the frequency spectrum of “Om” contains resonant frequencies of several sub-selves and induces large sub-selves. Also the healing effect of music and sounds could rely on this mechanism.

Focusing attention to some instrument producing melody creates kind of figure-background relationship. This requires that entire instrument playing the melody is represented by “instrument self”. An interesting possibility is that various instruments give rise to their own ensembles of frequency-selves. Note that the model makes it easy to understand why experienced performance is not simply the sum of individual performances. Music experience is a complicated self-organization process in which parts compose to wholes by quantum entanglement and vice versa according to how the listener directs his/her attention.

2.5.7 A model for harmony and genetic code

I have constructed a model of music harmony predicting also genetic code correctly and actually even the fact that there is variant of code involving two additional amino-acids [K22]. The model relies on two observations. Icosahedron has 12 vertices - the number of notes in 12-note scale - and 20 faces (triangles), which is the number of amino-acids.

The obvious idea is that amino-acid sequences define sequences of 3-chords defined by the notes at the vertices of the face representing amino-acid. DNA would represent the notes as a sequence of chords and amino-acid would play these notes. As a matter of fact, it turns out that DNA can be seen as a representation of music with a harmony defined by 64 3-chords corresponding to the DNA codons.

One ends up to the proposal that music harmonies are induced by non-self-intersecting imbeddings of 12-note scale as a quint cycle at icosahedron with the edges of the curve connecting neighboring vertices. This kind of cycles are known as Hamiltonian cycles. The 3-chords defined by the triangular faces of the icosahedron assign a notion of harmony to a given Hamiltonian cycle.

The surprising finding is that the symmetries of the resulting Hamiltonian cycles correlate strongly with the structure of genetic code. The numbers of faces at orbits of given face correspond to the numbers of DNAs coding for corresponding amino-acid. One can identify 60 DNAs in terms of 3 Hamiltonian cycles with different symmetry (Z_n for $n = 2, 4, 6$).

60 DNAs are not quite enough, and one has also the problem that already Pythagoras encountered: the 12 quints give slightly more than 7 octaves. One can add an additional tetrahedron to get 64 DNAs. One can glue it to a preferred face of icosahedron to get 13th note differing slightly from one of the notes of the scale. One can also add the tetrahedron without gluing. This gives two genetic codes and 2 additional amino-acids.

The outcome is a geometric representation of both music and genetic code. There are actually 256 different harmonic representations of codes with 64 basic chords defining the particular harmony. The proposal is that DNA and amino-acid sequences correspond to chord sequences and that chord sequences define a fundamental representation of emotions as music. The music can also correspond to light: dark photon triplets with frequencies in range of - say - audible sounds. Bio-photons would result from the decay of these photon triplets. One can imagine that various biomolecules are named by chord sequences just like the characters in Wagner’s operas correspond to themes. An interesting question is whether these dark photon triplets are negentropically entangled and can serve as analog of metabolic energy.

Music is a manner to express and induce emotions. This suggests that DNA might have additional aspect corresponding to these 256 different options perhaps serving as correlates for moods. The additional aspect might relate to the magnetic body of DNA giving rise to the cyclotron frequencies from which the chords are built. The 3-chords defined by dark photons could serve as a fundamental correlate for emotions and might define fundamental control and communication mechanism based on resonance phenomenon.

3 Whole-Body Consciousness: Physical Evidence And Tests

Whole-body consciousness is one of the predictions of the proposed theory and anomalously low dissipation can be regarded as the most dramatic physical signature of whole-body consciousness. This prediction provides a manner to test the theory.

3.1 Dissipation And Consciousness

The state function reduction sequence is a binary process which at a given step splits a subsystem into a unique pair of un-entangled subsystems if the subsystem allows decomposition to free entropically entangled systems. The process is random and explains second law and dissipation as a transformation of ordered energy to non-ordered energy. In standard view about self-organization the generation of structures requires a feed of ordered energy to compensate the dissipation.

In TGD framework the function of the metabolic energy feed would be more complex than this. Energy feed is necessary in order to avoid the formation of large sized entropically bound sub-selves. The fed energy need not be ordered. The rate of dissipation depends on how small the scale of the non-decomposable systems is. If negentropic entanglement binds mental images to larger ones, the rate of dissipation is expected to be low. Ordered metabolic energy can be also transformed to the energy carried by negentropic entanglement and liberated as the entanglement transforms to ordinary free or bound state entanglement.

The overall picture is also made more complex by the simultaneous presence of several length scales in which the state function reduction process proceeds so that it makes sense to speak about quantum parallel dissipation.

3.1.1 EEG waves and parallel information processing

Parallel information processing requires a large number of correlated units acting in parallel. If the units correspond to sub-selves which are bound state entangled, the whole system acts like a single neuron so that the information processing is very un-effective. If the system consists of unentangled sub-selves, the correlations are absent and the system is analogous to a statistical ensemble rather than a quantum parallel computer. If the entanglement is negentropic, one achieves parallel information processing since sub-selves are correlated but have not lost their degrees of freedom.

In synesthesia synchronous firing is observed and the cognitive and memory feats of synesthetes suggest that parallel information processing and negentropic entanglement (see **Fig. <http://tgdtheory.fi/appfigures/cat.jpg>** or **Fig. ??** in the appendix of this book) are involved. Therefore synchronous firing and its EEG counterpart define candidates for the physical correlates of the negentropic entanglement. TGD inspired model for EEG and nerve pulse predicts both propagating EEG waves associated with neural circuits and non-propagating EEG waves associated with entire regions of brain (say gap junction connected cell groups) [K25].

It would be natural to assign non-propagating EEG waves to synchronous firing of neurons forming a single coherent unit. However, if neurons form a bound state they act in unison and the information processing is very un-effective. Hence both propagating and non-propagating EEG waves should be present during parallel information processing periods and add up coherently. Synchrony would mean that standing wave part of EEG is for neurons like the rhythm of music for a ballet group. Coherence of EEG, one form of “oneness”, would be the correlate for presence of both reductionistic and holistic aspects of consciousness.

3.1.2 Evidence and tests for a reduced metabolism as concomitant of whole-body consciousness

Consider now possible evidence and tests for the reduced metabolism as a signature of whole-body consciousness.

1. In synesthesia different sensory modalities are associated with a regular manner just as thoughts are associated with speech. A dramatic signature of synesthesia is the lowering of the cortical metabolism by as much as about 18 per cent from the average (synesthete should become blind or paralyzed if standard wisdom would hold true!). This is what is expected if the neurons of left cortex get entangled. Also a large scale entanglement with parts of limbic brain, with sensory organs associated with coupled sensory modalities, and magnetic body is possible. The extended self in state of oneness does not dissipate significantly.
2. The metabolism of trained yogis provides a test for the hypothesis: measure some signatures for neuronal or cellular dissipation occurred during the meditative state and find whether

the dissipation is reduced during meditation. The lowered dissipation rate could even lead to the lowering of the body temperature or the temperature of nearby region.

3. There are even anecdotal claims about the ability of the dead bodies of gurus to resist natural decay. I am not certainly trying to convince any sceptic and, still having very living personal body, I have no personal opinions about the reality of the claimed phenomena. It would be however good to be open-minded.
4. There is (I believe well documented) phenomenon in which persons in trance are able to dance on burning charcoals without any disastrous consequences. Certainly there are standard science explanations for this. A possible nonstandard science explanation is that state of a whole-body consciousness is involved and no dissipation in cellular scale occurs. Since dissipation is not possible, the irreversible effects caused by the heat flow from burning charcoals are not possible and only reversible and curable effects can occur.
5. The reduction of the dissipation rate in some length scales should occur also during sleep, which is one example of this kind of state (obviously a reduction of metabolism occurs).
6. Also hypnosis might involve (possibly negentropic) quantum entanglement between some part of the brain of subject person and hypnotizer. This could reflect itself as correlations between EEGs of hypnotizer and subject person.

3.2 EEG Synchrony And Negentropic Entanglement

If one accepts the vision about life as something in the intersection of real and p-adic worlds 40 Hz EEG synchrony can be interpreted as a correlate for the generation of negentropic entanglement between cortical neurons. Before proposing this interpretation let us first describe the experimental findings of a finnish neuroscientist Antti Revonsuo [J10].

3.2.1 Findings

The interpretation for 40 Hz EEG frequency inspired by the binding hypothesis is as a synchronizing frequency necessary for the generation of unified percepts. This hypothesis has been studied using auto-stereograms [J10]. There was no detectable difference in the power spectrum at 36-44 Hz range in the situation when auto-stereogram was experienced as a set of random dots as compared to the situation when it was perceived as a coherent, symmetrical gestalt. The situation was same also in 8-13 Hz and 13-20 Hz beta bands. The finding is consistent with the place coding hypothesis.

On the other hand, when the conscious percept was transformed from a random set of points to a coherent gestalt, there was a detectable increase in 40 Hz power in the occipital and right posterior sites for EEG electrodes in a time window 500-300 ms before the unified percept was reported. There could be also some time lapse between the unified percept and the report about it but probably this cannot explain the entire lapse. No increase of power in beta bands was detected: this might be due to the fact that the widths of the measured bands are much wider than the widths of the narrow sub-bands reported masked by other EEG activity according to [J24]. Note that in the model for a hierarchy of EEGs based on dark matter hierarchy beta band correspond to data communicated to the magnetic body [K11].

That the change in activity is associated with the emergence of a new percept suggests that the temporary increase of the EEG power could be assigned to the communications of the forming percept to the magnetic body.

3.2.2 Interpretation in terms of generation of negentropic entanglement

A fresh view about what really happens during 40 Hz synchrony came with the realization that negentropic entanglement is possible in the intersection of real and p-adic worlds. The generation of negentropic entanglement between two sub-selves means that the corresponding mental images are fused [K28, K20]. The process is experienced by the fusing sub-selves as an expansion of consciousness whereas consciousness is lost when when bound state entanglement is generated. Also the meditative states begin with enhanced 40 Hz activity and the interpretation would be same.

Quite generally, the generation of negentropically entangled neuron groups could be a correlate for the emergence of a new idea or a new holistic pattern emerging from a chaos. Synchronous firing would be a natural correlate for the synergic state resulting in this manner. The paradoxical looking reduction of the oxidative metabolism associated with 40 Hz firing could be seen as a signature of reduced dissipation when dissipating ensemble of neurons forms a single quantum coherent system.

What could then be the interpretation of the 300-500 ms time scale and synchronous firing in TGD framework?

1. If one assumes that only brain is involved, one must answer whether the new percept emerges after such a long time period. One would naively expect that negentropic entanglement immediately gives rise to the percept. Negentropic entanglement however means that a quantum superposition of several alternative percepts is involved. In the beginning the new percept is present with only small probability so that one would only know that the moment of heureka is quite near (this is indeed the experience that one has) and in the final situation it dominates but not completely since it requires conscious effort to preserve the percept.
2. Also magnetic body should be involved in TGD framework. The natural question is “Why this synchronous neuronal firing?”. The natural answer would be that it allows to communicate the new percept as a consequence of a generation of negentropic entanglement to the magnetic body. The frequency scale of 40 Hz corresponds to a time scale of 25 milliseconds and corresponds to a length scale involved is about $.75 \times 10^7$ m, a good candidate for the size of the part of the magnetic body involved. This time scale is much shorter than 300-500 seconds. If the layer of the magnetic body in question corresponds to the fundamental 100 millisecond time scale assignable to electron as is natural in case of sensory percepts, the time lapse could be essentially due to the communication. If one takes the time scale literally the value of Planck constant which is about 3 to 5 larger than its standard value would suggest itself. Of course, the development of the percept from a fuzzy inkling to the final heureka could involve several communication loops between brain and magnetic body so that the interpretation as a lapse due the slowness of communications need not be inconsistent with the first interpretation.
3. The time scale 300-500 ms could characterize the duration of negentropic entanglement but this is not necessarily the case since negentropic entanglement would be un-necessary after the percept has been represented symbolically so that one knows what is lurking behind the chaos.

3.3 Synesthesia

Synesthesia [J25] seems to give a direct experimental evidence for a reduced rate of metabolism in “negentropic” states of mind. Synesthesia provides an excellent counter argument against the idea that sensory organs are primary experiencers unless one is ready to believe that cross-modal associations involve macroscopic quantum systems formed by the primary sensory organs involved and parts of brain.

TGD based quantum model for EEG and nerve pulse suggest that synesthesia is a natural by-product of the negentropic states of mind involving enhanced EEG in large regions of brain. Coherent large amplitude EEG induces synchronous neural firing in memory circuit containing hippocampus and thalamus. This leads to a “leakage” or nerve pulse activity in lateral thalamic nuclei from inducing sensory pathway to the induced sensory pathway.

An interesting possibility is that the non-propagating EEG waves predicted by TGD [K25] and possibly explaining the ability of right brain hemisphere to process information in a parallel manner are involved in synesthesia. The left brain hemisphere of synesthetes would be in some aspects like the right one during synesthesia and right and left brain could act like single conscious unit during synesthesia.

3.3.1 Does synesthesia involve left cortex whole-body consciousness?

The following aspects of synesthesia suggest that left cortex whole-body consciousness might be involved with it.

1. Synesthesia depends on left brain hemisphere only. A dramatic signature of synesthesia is the lowering of the metabolism in the left cortex by about even 18 per cent compared to the baseline (synesthete should become blind or paralyzed if standard wisdom holds true!). This is accompanied by relatively enhanced limbic expression. Hippocampus, which is believed to be crucial for long term memories, is critical for the synesthetic experience.
2. Synesthesia is emotional: the experiences are accompanied by a sense of certainty (“this is it”) feeling. This is in accordance with the observation that limbic brain expression is enhanced.
3. Holism is an important aspect of synesthesia. Synesthetes can precisely remember entire passages of text (which actually means that also reductionistic aspect is present), re-experience entire episodes of previous life, remember precise locations of various objects in a room. Synesthetic experiences are emotional. Synesthetes also tend to have “unusual experiences” like *deja vu*, *clairvoyance* and *pre-cognitive dreams*. This kind of personality constellation characterizes temporal-limbic epileptics.
4. Synesthetes have un-even cognitive skills. *Dyslexia*, *dyscalculia* in some degree, inability to transform words to digits, right-left confusion, etc.. Synesthetes are also non-right-handed.

A possible TGD based interpretation is that part of the left cortex is in whole-body consciousness in the sense that mental images have fused negentropically to very few larger mental images and there are very few unentangled sub-selves (mental images).

1. In this state left cortex does not dissipate as much as usually. Negentropic entanglement explains why the metabolism can be reduced during synesthesia below the level causing death under normal circumstances. The relative enhancement of metabolism in left limbic brain could relate to emotionality but does not favor negentropic entanglement in left limbic brain.
2. Also the cognitive impairments can be understood. The negentropic entanglement is both time-like and space-like so that these sub-selves have also a long duration. The resulting experience is holistic both in spatial and time direction with overall gestalt being more important than details. A good temporal resolution is essential for the mentioned cognitive skills and the explanation for cognitive dis-abilities is that entangled left cortex does not generate temporal sequences of sub-selves of short duration defining the mental clock readings or beacons. The mental images are extremely informative but the lack of linguistic expression based on the replacement of the percept with a collection of distinct objects mapped to linguistic symbols disfavors this mode of consciousness. Therefore linguistic cognition is favored by the practicalities of the everyday social life. The lack of asymmetry between brain hemispheres behind holism-reductionism dichotomy essential for language would naturally relate to non-right-handedness and the difficulty to distinguish between right and left. This inability would also conform with the view that some regions of right and left hemisphere are negentropically entangled.
3. The exceptional episodal memory achievements could be understood as a formation of large scale negentropic mental images which are stable so that long sequences of events of geometric past are re-experienced. In [K24] a model for long term episodal memories as questions sent to the geometric past inducing time-like entanglement with the self of the geometric past making possible episodal memory as a shared sensory experience is discussed. The question sent to the geometric past is coded to the light-like vacuum current associated with a stationary ME, usually in right brain but in left brain in case of synesthesia. The time like entanglement of the space-time sheets located in the geometric now and past (or future in case of *clairvoyance*) makes possible the episodal memory.

The proposed mechanism could also explain both the extraordinary memory feats of some autistic persons and their difficulties with the challenges of the everyday life. Dramatic example is a person able to draw from memory an area of London with size of several square kilometers as seen from air. The same person draws from memory a building having hundreds of windows and the number of windows comes out correctly although this same person is not able to count

correctly the number of three objects. As in the case of synesthetes cognitive impairments could be necessary prerequisites of the extraordinary gifts. Although the person cannot count how many windows the mental image of the building has, he can draw them correctly just by drawing along the image he sees in full concreteness.

3.3.2 Basic observations

The following observations provide a valuable information making possible to construct a more detailed model of synesthesia.

1. Synesthesia is in-voluntary and usually uni-directional: for instance, auditory experience creates visual association but not vice versa. Cross-modal associations, just like ordinary associations, do not change in the course of time. It has not been possible to find any rule telling which kind of associations are possible. It seems that cross-associated experiences are however generic and simple so that one can speak of form invariants which are kind of primitive building blocks of perception: for instance, visual associations tend to be blobs, lines, spirals and lattice shapes.
2. Synesthesia is projected: synesthetes experience their secondary sensory experiences in the space in the immediate surroundings of the body, never at large distances as is in principle possible in the case of vision and hearing. For instance, visual associations are seen on screen near to eyes.
3. The reduction of the metabolism is concentrated in the cortical regions whereas relatively enhanced metabolism occurs in the limbic brain, in particular hippocampus. Seizure discharges in hippocampus induce synesthesia in non-synesthetes: associations are simple experiences and become more complicated if seizures spread to the temporal lobes. The exceptional activity of hippocampus correlates with the exceptional ability to have precise episodal memories.
4. According to [J25] it is very rare that taste or smell is a synesthetic response or trigger of it. In fact that author of the articles knows no case in which smell alone would be the inducing sensory modality. This could relate to the fact that olfaction is exceptional sensory modality in the sense that there are two olfactory pathways: the first one projects directly to amygdala whereas second projects to cortex via thalamus as do also the sensory pathways associated with other sensory modalities [J18]. Furthermore, the olfactory pathway to the thalamus projects to the medial dorsal nuclei whereas other sensory pathways project to the lateral dorsal nuclei.
5. Synesthesia can also generate sensory-motor associations. For instance, visual input can generate well defined motor outputs and synesthete can express sensory experiences by dancing!

3.3.3 Memory coordination circuit and Papez circuits as brain circuits possibly involved with synesthesia

Hippocampus is believed to be crucial for the formation and experiencing of long term memories. This suggests that an enhanced activity in some neural circuits involving hippocampus in a form of increased EEG amplitudes (at theta frequencies) is essential for generating the sensory leakage between neural circuits and sensory pathways leading to synesthesia. For this kind of mechanism synesthetic mode need not be the only mode of experiencing: ordinary and synesthetic modes could also alternate. If synesthetic and non-synesthetic periods alternate, synesthesia cannot interfere radically with the real experience. This is clearly the safest option and perhaps favoured by natural selection. The ability to control theta wave amplitudes in hippocampus could make possible an artificial generation of synesthesia.

There are two important circuits going through hippocampus [J13]. The first circuit is memory coordination circuit having the following structure:

1. Lateral dorsal nucleus and anterior nuclear group of the thalamus
2. Cingulate cortex

3. Subiculum and the rest of the hippocampal formation with input via entorhinal cortex and output via the subiculum and fornix
4. Back to 1.

Fornix is known to be the circuit responsible for slow theta rhythm of about 3-7 Hz, which does not correspond to a conscious experience: thus memory coordination circuit is believed to be unconscious to us under normal circumstances [J13]. Temporal cortex contains a region which projects to hippocampus and receives input from all sensory modalities. Memory circuit is believed to somehow to provide a handle to the memory constellations believed to reside in the temporal lobes. That the EEG amplitude associated with the fornix would be exceptionally large during synesthesia is in accordance with the fact that that synesthetes tend to have personal constellation of limbic-temporal epileptics. Also the abnormal episodal memories (Nabokov is one of the best known synesthetes with miraculous memory) supports resonance in this circuit. Only memory circuit projects to the thalamic nuclei receiving both sensory and motor input. Hence also the occurrence of the motor synesthesia supports the view that the sensory leakage occurs in the thalamic nuclei contained by the memory circuit.

Papez circuit is second circuit containing hippocampus. Papez circuit has following structure:

1. Anterior nuclear group of the thalamus
2. Cingulate cortex
3. Hippocampal formation
4. Hypothalamus
5. Back to 1.

The enhanced activity of the Papez circuit induced by the hippocampus could correlate with the emotionality of the synesthetic experience.

3.3.4 The general picture about the sensory leakage

These observations and facts suggests the following general model for synesthesia.

1. Contrary to the original expectations, the hypothesis that the primary sensory qualia are associated with the sensory organs can be defended against various objections if one assumes that brain and sensory organs quantum entangle so that a fusion of sensory mental images with cognitive mental images occurs. The hypothesis explains elegantly the differences between imagination, dreaming, hallucinations, and ordinary sensory experience. Dreams and hallucinations would involve a back projection from brain to sensory organs giving rise to a “qualification” of the cognitive mental images represented by the nerve pulse patterns. In the case of synesthesia the back projection would assign to a sensory input from the inducing sensory modality an artificial sensory input in the induced sensory modality.
2. If the cross-modal communication between sensory organs occurs through thalamic nuclei common to the cross-associated sensory modalities, one can understand why smells alone are never the inducing sensory modalities. Lateral dorsal thalamic nuclei would be the sites of the sensory leakage. Furthermore, in the case of hearing, vision, and tactile senses it is easy to produce artificial sensory experience than in case of chemical senses (molecules attaching to the sensory receptors would be required).
3. The possibility of the sensory-motor synesthesia suggests that the back-projection involves artificial sensory input to the motor organs inducing a motor activity, which in TGD framework corresponds to a geometric time reversal of the sensory perception starting from the level of motor organs and proceeding in a time reversed direction. Only memory coordination circuit involves thalamic nuclei receiving both sensory and motor inputs. Memory coordination circuit involves lateral dorsal nuclei (all modalities except olfaction) but not medial dorsal nuclei (olfaction). This leads to the hypothesis that the exceptionally high activity of the memory coordination circuit induces a sensory leakage in the lateral dorsal nuclei of the thalamus belonging to the memory coordination circuit.

3.3.5 Synesthesia as a sensory leakage between thalamic nuclei common to the memory coordination circuit and primary sensory pathways

Synesthesia could be a byproduct of an abnormally large EEG amplitude in the memory coordination circuit and possibly also Papez circuit inducing a “leakage” of nerve pulses between sensory pathways in thalamus in turn giving rise to synesthetic crossmodal associations. That synesthetic associations are projected, is consistent with the sensory leakage hypothesis.

The resonant EEG amplitude associated with the thalamic nuclei of the resonating memory coordination circuit spreads out to the primary sensory or motor pathways in the physical vicinity of the resonating pathway and generates a sensory leakage and a back projection to the sensory organs of the induced modality thus inducing synesthesia. The structure of the synesthetic association is determined by the pattern of neurons activated and thus creating the virtual sensory input back-projected to the sensory organ of the induced sensory modality. One can imagine each neuron as a pixel of a sensory picture and the pattern of activated pixels determines the synesthetic association.

The model makes testable predictions.

1. The assumption that the sensory leakage occurs in the thalamus could be tested. One could study whether the crossmodal associations change, when the sensory input from right or left side of body is lacking. For instance, one could find what happens if audio-to-visual synesthete blocks left/right ear during audio-to-visual synesthesia.
2. The generation of artificial sensory experience by back-projection to the sensory organ of the induced sensory modality means that a permanent or an artificially induced temporal loss of the induced sensory modality (by a local anaesthesia of the axons of the sensory pathway) should lead to the loss of the synesthesia.

3.3.6 How to understand the memory feats of synesthetes and the reduced metabolism in the left hemisphere?

Negative energy MEs can be interpreted as classical signals sent to the geometric past, and they could be crucial for an active memory recall involving a question sent from the magnetic body to the brain of the geometric past as a negative energy ME. Also chemical signals- say very slow Ca^{++} wave inside brain- could be involved and could define the classical response to the negative energy signal.

1. Memories and time mirror mechanism

Time mirror mechanism (see **Fig.** <http://tgdtheory.fi/appfigures/timemirror.jpg> or **Fig. ??** in the appendix of this book), which was first developed in the framework of positive energy ontology, is the simplest quantum mechanism of memory. Its recent formulation goes as follows.

1. The mechanism of episodal memory is assumed to involve only a sharing of mental images by negentropic time-like quantum entanglement. The notion of bound state entanglement in time direction need not make sense at all: the reason is that bound state energy is assigned with the entire system rather than sub-systems and for zero energy states total energy is always zero. Hence it seems better to assume that only negentropic entanglement and non-binding real entanglement in time direction is possible.
2. The basic question is what really distinguishes between verbal (declarative) and episodal memories. Is the difference between verbal and episodal memories related only to the temporal size scale of the negentropically entangled subsystems? In this case declarative memory would consist of a sequence of short lasting episodal memories with contents which are symbols rather than direct sensory perceptions with emotional content. Or can one interpret verbal memories as purely classical communications between geometric past and future? This would make sense if declarative memories result when an entropic entanglement between future and past selves is reduced to zero so that the communications would reduce to those between non-living systems. Episodal memories would be possible in the intersection of the real and p-adic worlds and declarative memories everywhere. This interpretation is consistent with the earlier vision.

One can model the memory recall as follows.

1. The view about memory recall is that a “question” realized as a negative energy ME is sent from magnetic body to the brain of the geometric past, it is reflected back as a positive energy signal, and returns back to the magnetic body. It is essential that the signal is between different CDs - say CD and its and sub-CD- rather than future and past boundaries of single CD.
2. One must be very careful with what negative energy signal really means. This signal would be generated in quantum jump and should connect the past boundary of CD to the future boundary of a CD in the geometric past- say for definiteness a sub-CD of CD itself if personal memory is in question. The condition that the positive energy of the past boundary of CD remains unchanged means that the energy flowing to the direction of future inside CD is increased as a recoil effect. The same applies in the case of sub-CD. This interaction could be seen as an interaction between two CDs implying an exchange of energy between the positive energy parts of the states.
3. The transfer of negative energy to the past can transform the positive energy part of the state of the geometric past to a bound state in the ordinary sense of the word. If positive energy negentropic entanglement is in question this need not happen although the energy of the state is reduced. Therefore negentropically entangled mental images are especially interesting from the point of view of episodal memories. The question and answer fuse to a single negentropically entangled mental image shared by the hemispheres of the geometric past and now. The negentropy of the past state is expected to reduced as its energy is reduced so that quite literally a flow of information to future is in question.
4. Duality between memory and recognition suggests itself. What is memory from the point of view of future CD could be precognition from the point of view of past CD.

The generation of negative energy MEs would involve a phase transition to a state in which the positive MEs propagating along axons with a subluminal effective phase velocity transform to negative energy MEs leaving the brain and are reflected back in time direction. Synchronous membrane oscillations could accompany negative energy MEs [K23]. If negative energy MEs are sent by the region of the left brain hemisphere, it gains some energy by pay now-let others pay mechanism.

2. Reduction of metabolism during synesthesia

Episodal memories could relate to the reduction of the metabolism by 18 per cent during synesthesia.

1. The original interpretation proposed before the formulation of zero energy ontology was that the generation of the negative energy MEs is forced by the starvation of the neurons induced by the over-activity of the neurons of the memory coordination circuit. The miraculous ability of synesthetes to remember episodally could be understood to result as a by-product of a neuronal emergency reaction. The starving cortical neurons of the left hemisphere would send negative energy MEs to the direction of the geometric past inducing entanglement bridges by the mirror mechanism with the brain of the geometric past in turn inducing episodal long term memories by the sharing of the mental images. The same mechanism might work also in the normal situation but involve a less dramatic artificial starvation.
2. The reduction of the metabolism could be also mostly due to the negentropic entanglement for the mental images in the left cortex “now” so that the episodal memories realized in the proposed manner would give only an additional reduction to metabolism.

3. Non-episodal memories

Also in the case of non-episodal memories the question to the geometric past could be communicated by the mirror mechanism using negative energy MEs but now time-like entanglement would be entropic free entanglement and would be reduced to zero in quantum jump so that the real answer would be communicated classically.

1. The classical signal could return to the magnetic body along reflected positive energy ME so that the question and answer could use the same cognitive code.
2. Second possibility is that signal returns back without leaving the brain. The classical signal sent by the left hemisphere of the geometric past to the left hemisphere of the future would propagate a finite distance L within brain in a time interval T defining the temporal span of the memory (say years) so that the ME would propagate with an effective phase velocity $v = L/T$. The velocities of Ca^{++} waves span an extremely wide spectrum and provide a natural candidate for the physiological excitations in question [J19].
3. Ca^{++} waves could be also be accompanied MEs with ultraslow phase velocities.

4 Self Hierarchy And The Notion Of Magnetic Body

TGD not only predicts infinite hierarchy of selves but also strongly suggests that “me” as an intentional agent should be identified as my field body, or perhaps better to say, my magnetic body having an astrophysical size. Magnetic body would also serve as an intentional agent and controlling biological body by time mirror mechanism. An entire hierarchy of magnetic bodies is predicted since the flux quanta of each body part define corresponding magnetic body. Also the magnetic body of Earth should define a conscious unit, kind of Magnetic Mother Gaia perhaps responsible for some third person aspects of our consciousness. The role of the magnetic body would be like that of a manual of an electronic instrument, that is it would provide a higher level representation for the body and its environment. Magnetic body would also serve as template for the formation of bio-structures. Magnetic body would share the mental images produced by brain as symbolic representations of the sensory input. Also time mirror mechanism of long term memories and Uncertainty Principle applied to EEG provide support for the notion. Some experimental findings supporting the notion of field body are Libet’s findings, the role of Schumann resonance frequency for consciousness about time delays of consciousness, and the effects em radiation on brain and living matter at cyclotron frequencies.

This original version of this section was written much before the emergence of the zero energy ontology. A first principle justification for the notion of magnetic body is provided by zero energy ontology predicting that primary p-adic length scales are accompanied by secondary p-adic length scales (as well as time scales). For instance, in case of electron the secondary time scale is .1 seconds and correspond to a length scale of order Earth’s circumference. It is natural to assign this time scale to the flux tubes of the magnetic body. This aspect will not be discussed explicitly in the sequel but should be kept in mind.

An important question concerns about actual biological realization of the self hierarchy predicted to begin already at elementary particle level and continuing indefinitely. TGD indeed leads to rather concrete ideas about how this hierarchy is possibly realized.

4.1 Higher Level Selves In Biological Self Hierarchy

The basic inputs for the speculations about the higher levels of the biological self hierarchy are topological field quantization, the idea of memetic code and the observations about the effects of EFL em fields to brain suggesting that the higher levels correspond to em selves with sizes of order wavelength of photons generated by EEG currents having size of order of Earth and realized as topological field quanta. The general view about symbiosis of hierarchies of massless extremals (MEs) and superconducting magnetic flux tube structures with the ordinary matter at atomic space-time sheets provides strong constraints on the speculations. The general vision about sensory representations realized in terms of magnetic flux tube structures outside brain [K24] and having sizes of ELF wavelengths leads to rather concrete ideas about the self hierarchy and about our position in it.

4.2 Quantum Criticality

Quantum criticality is one of the basic guiding principles of Quantum TGD. What it means mathematically is however far from clear and one can imagine several meanings for it.

1. What is obvious is that quantum criticality implies quantization of Kähler coupling strength as a mathematical analog of critical temperature so that the theory becomes mathematically unique if only single critical temperature is possible. Physically this means the presence of long range fluctuations characteristic for criticality and perhaps assignable to the effective hierarchy of Planck constants having explanation in terms of effective covering spaces of the imbedding space. This hierarchy follows from the vacuum degeneracy of Kähler action, which in turn implies 4-D spin-glass degeneracy. It is easy to interpret the degeneracy in terms of criticality.
2. At more technical level one would expect criticality to correspond to deformations of a given preferred extremal defining a vanishing second variation of Kähler action or Kähler function.
 - (a) For Kähler function this criticality is analogous to thermodynamical criticality. The Hessian matrix defined by the second derivatives of free energy or potential function becomes degenerate at criticality as function of control variables which now would be naturally zero modes not contribution to Kähler metric of WCW but appearing as parameters in it. The behavior variables correspond to quantum fluctuating degrees of freedom and according to catastrophe theory a big change can in quantum fluctuating degrees of freedom at criticality for zero modes. This would be control of quantum state by varying classical variables. Cusp catastrophe is standard example of this. One can imagine also a situation in which the roles of zero modes and behavior variables change and big jump in the values of zero modes is induced by small variation in behavior variables. This would mean quantum control of classical variables.
 - (b) Zero modes controlling quantum fluctuating variables in Kähler function would correspond to vanishing of also second derivatives of potential function at extremum in certain directions so that the matrix defined by second derivatives does not have maximum rank. Entire hierarchy of criticalities is expected and a good finite-dimensional model is provided by the catastrophe theory of Thom [?]. Cusp catastrophe (see <http://tinyurl.com/yddpfdgo>) [?] is the simplest catastrophe one can think of, and here the folds of cusp where discontinuous jump occurs correspond to criticality with respect to one control variable and the tip to criticality with respect to both control variables.
3. Quantum criticality makes sense also for Kähler action.
 - (a) Now one considers space-time surface connecting which 3-surfaces at the boundaries of CD. The non-determinism of Kähler action allows the possibility of having several space-time sheets connecting the ends of space-time surface but the conditions that classical charges are same for them reduces this number so that it could be finite. Quantum criticality in this sense implies non-determinism analogous to that of critical systems since preferred extremals can co-incide and suffer this kind of bifurcation in the interior of CD. This quantum criticality can be assigned to the hierarchy of Planck constants and the integer n in $h_{eff} = n \times h$ [K13] corresponds to the number of degenerate space-time sheets with same Kähler action and conserved classical charges.
 - (b) Also now one expects a hierarchy of criticalities and since criticality and conformal invariance are closely related, a natural conjecture is that the fractal hierarchy of sub-algebras of conformal algebra isomorphic to conformal algebra itself and having conformal weights coming as multiples of n corresponds to the hierarchy of Planck constants. This hierarchy would define a hierarchy of symmetry breakings in the sense that only the sub-algebra would act as gauge symmetries.
 - (c) The assignment of this hierarchy with super-symplectic algebra having conformal structure with respect to the light-like radial coordinate of light-cone boundary looks very attractive. An interesting question is what is the role of the super-conformal algebra associated with the isometries of light-cone boundary $R_+ \times S^2$ which are conformal transformations of sphere S^2 with a scaling of radial coordinate compensating the scaling induced by the conformal transformation. Does it act as dynamical or gauge symmetries?

4.2.1 Preferred extremals and criticality

Zero energy ontology (ZEO) was a great step of progress in the development of TGD. Now pairs of space-like 3-surfaces at the boundaries of causal diamond become the basic objects. It is important to notice that preferred extremal property itself in ZEO is un-necessary unless one requires Bohr orbit property: the reason is that for given pair of 3-surfaces at boundaries CD the space-time surface would be unique for deterministic dynamics. In the case of non-deterministic dynamics situation can change but this seems to relate to quantum criticality and hierarchy of Planck constants bringing in new degrees of freedom related to the non-determinism and to super-conformal symmetries acting as gauge symmetries.

Bohr orbit property would be space-time correlate for the correlations of the positive and negative energy states at the ends of CD and non-triviality of quantum dynamics so that preferred extremal property would be another name for Bohr orbit property. Therefore it seems reasonable to assume that the notion of preferred extremal indeed makes sense and is needed.

I have proposed several identifications for the preferred extremal property such as criticality of Kähler action, Hamilton-Jacobi structure space-time surface generalizing complex structure, quaternionic structure in tangent space. These characterizations might be equivalent.

2-D criticality suggests that conformal symmetries act as gauge symmetries for the deformations for which second variation of Kähler action vanishes and that there is finite number n of gauge equivalence classes which can be related to the hierarchy of Planck constants $h_{eff} = n \times h$. The space-time sheets connecting two 2-surfaces at the ends of causal diamond (CD) in zero energy ontology (ZEO) have same Kähler action and conserved charges. The n degrees of freedom would be discrete dynamical degrees of freedom and among other things could be responsible for the fractionization of charges.

4.2.2 Topological field quantization

Topological field quantization [K18] implies that various notions of quantum field theory have rather precise classical analogies. Topological field quantization provides the correspondence between the abstract Fock space description of elementary particles and the description of the elementary particles as concrete geometric objects detected in the laboratory. In standard quantum field theory this kind of correspondence is lacking since classical fields are regarded as a phenomenological concept only. Topological field quanta define regions of coherence for the classical fields and classical coherence is the prerequisite of the quantum coherence.

The energies and other classical charges of the topological field quanta are quantized if they correspond to preferred extremals meaning that the 3-surfaces at the boundaries of CD are correlated just like for Bohr orbits.

Feynman diagrams become classical space-time surfaces with lines thickened to 4-manifolds. For instance, “massless extremals” [K21] representing topologically quantized classical radiation fields are the classical counterparts of gravitinos and photons. Topologically quantized non-radiative nearby fields give rise to various geometric structures such as magnetic and electric flux tubes.

The virtual particles of quantum field theory have also classical counterparts. In particular, the virtual particles of quantum field theory can have negative energies: this is true also for the TGD counterparts of the virtual particles. The fundamental difference between TGD and GRT is that in TGD the sign of energy depends on the time orientation of the space-time sheet: this is due to the fact that in TGD energy current is vector field rather than part of tensor field. Therefore space-time sheets with negative energies are possible. This could have quite dramatic technological consequences: consider only the possibility of generating energy from vacuum and classical signalling backwards in time along negative energy space-time sheets [K2]. Also biosystems might have invented negative energy space-time sheets: in fact, so called “massless extremals” provide an ideal manner to generate coherent motions as recoil effects caused by the creation of negative energy massless extremals [K6]. An interesting possibility is that quantum entanglement has the formation of the flux tubes as its geometric correlate.

The hypothesis of topological self-referentiality stating that the topological field quanta of classical fields form a symbolic representation for the system’s properties, provides a strong interpretative tool. For instance, bound state entanglement is represented by negative energy MEs and the generation of macroscopic bound states essential for the binding of the mental images is

accompanied by the liberation of the binding energy as a usable energy. Hence the ability of the system to behave as a single coherent whole and non-local quantum metabolism are different sides of the same coin. The concept of field body (or electromagnetic body) consisting of the topological field quanta is also of central importance. Field body could be seen as a “manual” for the system providing a classical, topological representation for the quantum aspects of the material part of the system. The size of this field body is much larger than the material body of the system.

Topological field quanta (field bodies) could serve as templates for the formation of the biostructures. Thus topologically quantized classical electromagnetic fields could be equally important for the functioning of the living systems as the structures formed by the visible biomatter and the visible part of biosystem might represent only a tip of an ice berg.

4.2.3 Topologically quantized classical fields as templates for self hierarchy?

The web like structure formed by topological field quanta representing classical fields, in particular em fields, is reminiscent of structures formed by microtubules and collagens forming the connecting tissue of living systems. It has been already earlier suggested that magnetic flux tubes and other topological field quanta serve as templates for various biostructures in the sense that ordinary matter is topologically condensed on the flux tube like structures. This would mean that living systems would be only part of much larger web formed by Earth’s classical em field forming one particular sub-self of Mother Gaia.

The thickness for the flux tubes of Earth’s magnetic field is about $2/\sqrt{eB} \simeq 4 \times 10^{-6}$ meters for $B = .5 \times 10^{-4}$ Tesla. If magnetic flux tubes of Earth have direct geometric coupling with brain one could perhaps understand the miraculous ability of birds and bees to navigate using Earth’s magnetic field. The proteins navigating along microtubules, cells navigating along collagen fibres and birds navigating along Earth’s magnetic field lines would all be guided by higher level self! One could see also humans and the societies formed by them as continually self-organizing organs in the body of electromagnetic Mother Gaia. In this picture the so narrow wave cavity of radius 80 km between Earth’s surface and ionosphere could be like brain of Earth, which is very sensitive to the conditions of ionosphere and biosphere and has “biofeedback” coupling with living systems. The effect of oscillatory phenomena (sound, radiations and magnetic fields) at frequencies Schumann resonances on brain to be discussed below supports also the direct interaction of our brain with Mother Gaia via Earth’s electromagnetic field.

It is interesting to notice that the ratio of the thickness of solar corona (10^6 m) to the radius of Sun (5×10^8 m), the height of the wave cavity of Earth (80 km) to Earth radius (7×10^6 m), the ratio of the thickness of grey matter of cortex (1 mm) to the size of human brain lobe (10 cm) as well as the ratio of the thickness of cell membrane (10^{-8} m) to the radius of neuron (2.5×10^{-6}) have roughly the same value of order 10^{-2} . Thus it seems that cell membrane, cortex, electromagnetic cavity of Earth and solar corona might have similar role in the self hierarchy.

The web formed by topological field quanta of the classical em and fields continues to arbitrary long length scales. For instance, the flux tube structure of solar magnetic field provides an explanation for the anomalously high temperature of solar corona and a model for solar spot cycle [K27]. Perhaps also Sun is a conscious self forming part of “Indra’s net” representing electromagnetic and other classical fields of cosmos. Since the four CP_2 coordinates are the primary dynamical variables, one must consider the possibility that topologically quantized classical gauge fields and classical gravitational field could form rather independent sub-selves.

4.2.4 Possible geometric correlates of entanglement?

The geometric correlate for the entanglement between sub-systems is the generation of flux tubes combining the corresponding 3-surfaces to single 3-surface: this is nothing but the direct touching of the 3-surfaces. Actually, all that is needed is the fusion of the space-time sheets of same local topology (real or p-adic) to single sheet. The entanglement generated in this manner can be preserved even when direct geometrical contact between 3-surfaces is not present anymore. In TGD based model for brain these bonds are formed between parts of brain and sensory organs.

One can consider several models for flux tubes. Topological field quantization providing general description of classical gauge and gravitational fields in TGD framework implies that magnetic and

electric flux tubes and “massless extremals” (MEs) are the basic building blocks of classical em fields. All these structures can serve as flux tubes.

MEs are especially interesting candidates for space-time correlates of time like entanglement between positive and negative energy parts of zero energy states. MEs are very general solutions of field equations of TGD and have properties making them ideal for realizing basic functions of biosystems.

1. MEs represent propagation of classical gauge fields with light velocity and can carry non-vanishing vacuum em currents and hence give rise to coherent photons. A tentative identification is as bio-photons of Popp [I6]. The hypothesis is that MEs make possible generation of quantum entanglement between brain and sensory organs. In this manner they provide a realization for neuronal window idea generalizing the idea about hologrammic brain [K7]. MEs could make possible both classical (quantum) communication by the propagation of classical fields (coherent photons) along them and neuron could literally have a window to external world via sensory organ.
2. In TGD framework space-time sheets with negative time orientation are possible and carry negative classical energies (in General Relativity this is not possible). The generation of negative energy MEs provides “buy now, pay later” type mechanism for energy production. Generation of negative energy ME is classical counterpart for the generation of virtual particle and it is to be expected that the subjective lifetime of negative energy MEs is finite number of quantum jumps. Thus organism must eventually “pay”, that is to compensate for the dissipation of the energy gained by the generation of the ME by metabolism. Therefore metabolism is still needed. Even more, organism must be able to give guarantees that it can pay! The ability to provide these guarantees is perhaps one of the great achievements of the biological evolution.
3. MEs carry large momentum since all Fourier components of the gauge fields have parallel light-like momenta. Since classical 4-momentum is light-like, the amount 3-momentum per energy is maximal. Thus, if the system is able to generate ME by quantum jump, it gains automatically large recoil momentum. Hence MEs could provide the fundamental mechanism making possible the coherent macroscopic motion of living systems. Negative energy ME of this kind might be identifiable as a mind-like space-time sheet representing the geometric correlate for the conscious decision to move.
4. MEs represent dispersionless propagation of a pulse preserving its shape and are thus ideal for classical communication. If negative energy MEs are possible, one can imagine a mechanism of “real subjective time” communication between selves of either geometric past or future having arbitrarily large time-like distance. This idea is not conflict with standard classical causality at given space-time sheet. Needless to say, this kind of possibility would realize concretely the idea about four-dimensional society and revolutionize our view about universe: living beings separated by billions of light years could in principle have “real subjective time” chat.

4.3 Support For The Notion Magnetic Body

There exists both theoretical and empirical support for the notion of magnetic body.

4.3.1 Theoretical support

1. EEG and Uncertainty Principle

There are good reasons to expect that EEG is accompanied by radiation, which in TGD framework has topological light rays as space-time correlates. Typical EEG frequencies correspond to wavelengths $\lambda = c/f$ which for which natural length scale unit is Earth size. Thus Uncertainty Principle suggests that structures of at least this size are involved with the self hierarchy associated with the brain.

2. *p-Adic physics as physics of cognition*

p-Adic physics as physics of cognition is a fundamental key idea of TGD inspired theory of consciousness. For long time I believed that p-adic-to-real transformations of space-time sheets realized as quantum jumps could serve as correlates for the transformation of intentions to actions allow deeper understanding of also psychological time as a front of p-adic-to-real transition propagating to the direction of the geometric future. It turned out that the mathematical realization of this idea might involve unsurmountable challenges and the natural vision is based on adeles: both reals and various p-adic number fields would be present and cognition would be present already at elementary particle level as also the p-adic mass calculations suggest.

Intentional behavior means that there is unpredictability in short time scales but predictability in long time scales because system can realize its long term plans and use its partially free will to cope with the changing challenges of the everyday life.

p-Adic topology differs radically from real topology in the sense that p-adically infinitesimal is infinite in real sense.

1. The rational values of real and p-adic imbedding space coordinates correspond to the same points of the generalized imbedding space (essentially union of real and p-adic imbedding spaces for various values of p with rational points common to all number fields and also points, in particular points with algebraic number valued coordinates, shared by different number fields in a pair-wise manner identified).
2. The points, which are p-adically close to each other can have arbitrarily long real distance since the points x and $x + kp^n$, $k \in \{0, p-1\}$, become arbitrarily near to each other p-adically and arbitrarily far way in real sense as n increases for the p-adic topology characterized by prime p .

This means that intentionality and cognition are literally cosmic phenomena and present in all scales and evolution of cognition proceeds from long p-adic length scales to short ones in real sense (but from short to long scales in p-adic sense). The carving of a statue by starting from a rough sketch and adding details gradually is a good metaphor for what is involved. Development of any motor skill, say piano playing, is an excellent example of what happens.

Zero Energy Ontology (ZEO) leads to a rather precise view about volitional action. In ZEO self corresponds to a sequence of state function reductions occurring at fixed boundary of causal diamond (CD). Volitional action begins with the first state function reduction to the opposite boundary of CD involving “death” of corresponding self and re-incarnation at opposite boundary [K29, K1]. Volition can be also seen as a transformation of intention to action. In the original vision this transformation was identified as p-adic-to-real phase transitions of space-time sheets taking place in quantum jumps. It has however turned out that this assumption creates more problems than it solves and that it is un-necessary if one accepts the adelic view meaning that the physics associated with all number fields form a coherent whole and p-adic physics is correlate for cognition. One can say that cognition is in the intersection of reality and various p-adicities defined by strong form of holography as string world sheets with the property that the parameters involved with their mathematical characterization are in algebraic extensions of rational numbers and can be thus algebraically continued to real and various p-adic number fields.

Negative energy topological light rays (MEs) provide an example of possible space-time correlates for intentional actions. Also wormhole magnetic fields consisting of pair of space-time sheets carrying magnetic fields of equal intensity and having opposite time orientations could be generated in intentional action.

In many-sheeted space-time (see **Fig.** <http://tgdtheory.fi/appfigures/manysheeted.jpg> or **Fig. 9** in the appendix of this book) particles topologically condense at all space-time sheets having projection to given region of space-time so that this option makes sense only near the boundaries of space-time sheet of a given system. Also transition increasing the p-adic length scale and thus the size of the space-time sheet could take place and the liberated energy would correspond to the reduction of zero point kinetic energy. Particles could be transferred from a portion of magnetic flux tube portion to another one with different value of magnetic field and possibly also of Planck constant h_{eff} so that cyclotron energy would be liberated. In the following only the “dropping” option is discussed.

3. Time mirror mechanism of long term memories

TGD based model of long term memory requires no storage of memories of past to the brain of the geometric now. The memories are in the geometric past as dynamical self organization patterns and subject to changes.

1. In the case of active memory recall the desire to remember is communicated to the geometric past by sharing and fusion of mental images made possible by entanglement. In the case of episodal memories also the memory recall would result in this manner. For non-episodal memories the memory would be communicated from the geometric past using classical communications.
2. In the case of episodal memories active precisely targeted memory recall might be difficult since the entanglement with a correct mental image seems to require good luck. In principle it is possible to select the distance T to the geometric past where the memory comes from by selecting the fundamental frequency of ME.
3. The most natural manner to realize the time mirror mechanism (see **Fig.** <http://tgdtheory.fi/appfigures/timemirror.jpg> or **Fig.** ?? in the appendix of this book) is to regard magnetic body as the system communicating with the brain of the geometric past serving as mirror. The fundamental frequency $f = c/L$ of associated with a topological light ray of length L would naturally code for the time span of the long term memory as $T = L/c$ in the sense that only these memories would be communicated resonantly. Thus the distance from brain along magnetic flux tubes would code the time span of the memory. Long term memories with a span of order lifetime however require that the size of the magnetic body involved is measured in light decades.

4.3.2 Experimental support for the notion of magnetic body

The work of Blackman and other pioneers of bio-electromagnetism concerning the effects of ELF (extremely low frequency) em fields on brain [J14] discussed in [K11], provides dramatic support for this idea and also a concrete view about how brain manages to act as macroscopic quantum system. The currents generating EEG certainly create weak electromagnetic radiation fields which in TGD framework correspond to topological field quanta of size of Earth having natural coupling to the magnetic flux tubes.

The lowest Schumann frequency is roughly $c/2\pi R$, R radius of Earth, and equal to $\omega \simeq 8$ Hz. It is known that EEG frequencies are in the same frequency range as so called Schumann frequencies 8, 14, 21, ... Hz [F1] associated with the resonances of the electromagnetic fields in the 80 km thick wave cavity between Earth surface and ionosphere. The higher EEG frequencies seem to correlate with higher Schumann resonance frequencies: in particular, the frequencies 13 and 39 Hz which are also cyclotron resonance frequencies of Na_+ , are very near to Schumann frequencies. Schumann frequencies vary in time and it has been found that also the variations of EEG frequencies correlate with this variation.

Magnetic perturbations near Schumann frequencies are known to have profound effects on human brain inducing altered states of consciousness and cortical instabilities such micro-seizures and epilepsies [J20]. The photons generated by Josephson currents associated with macroscopic ionic BE condensates have wavelengths of order Earth size and the topological field quanta representing classically the radiation field have size of Earth.

The explanation of the effects related to water memory [I3, I2] suggests that similar magnetic effects appear at much wider frequency range than ELF frequencies which would mean that the super-conducting magnetic flux tube circuitries form a fractal hierarchy. The findings challenging the notions of ionic pumps and channels [I7] provide additional strong support for the notion of many-sheeted space-time and hierarchy of super-conducting of magnetic flux tubes. The evidence for the fractal hierarchy of magnetic flux tubes is discussed in [K4, K5].

These observations support the view that our “physical” body is only a tip of an iceberg and formed by the topological condensation of the bio-matter around electromagnetic topological field quanta serving as templates for the bio-structures.

The findings of Libet [J15] about time delays associated with the passive aspects of conscious experience suggest that our sensor perceptions are a fraction of second old (.3-.5 seconds). This could be understood if the sensory percepts from brain are communicated to the magnetic body

identifiable as “us”. This particular time scale would correspond to a layer of magnetic body which has 3-5 times the size scale of electron’s CD which is about .78 times the circumference. A possible interpretation is in terms of dark electrons with a value of Planck constant which is 3-5 times the standard value. The corresponding EEG frequencies would vary in region.33-.2 Hz.

4.3.3 Cyclotron resonances as key to quantum consciousness

The estimate for the thickness of the magnetic flux tubes of Earth’s magnetic field based on the quantization of the magnetic flux is about cell size. There is direct evidence for the hypothesis that ions in the magnetic field of .2 Gauss (Earth) magnetic field has nominal strength of $B_E = .5$ Gauss) form quantum states with the characteristic energies of order 10^{-14} eV and size of the orbit being of order $2/\sqrt{eB}$, that is cell size: in fact, the value $.5 \times 10^{-4}$ Tesla for Earth’s magnetic field corresponds to the length scale $L(169) \simeq 5 \mu m$ rather precisely. This length scale is indeed the p-adic length scale which seems to correspond to our sensory consciousness and various macroscopic quantum phases seem to reside at $k = 169$ space-time sheets probably forming join along boundaries/flux tube condensates. The work of Blackman and other pioneers of bioelectromagnetism concerning the effects of ELF (extremely low frequency) em fields on brain [J14] provides dramatic support for this idea and also a concrete view about how brain manages to act as macroscopic quantum system.

The discovery of Blackman means that frequencies having special effect on biomatter correspond to cyclotron resonances for ions like Ca_{++} , Na_+ , K_+ and Cl_- in magnetic field $B = 2B_E/5 = .2$ Gauss. The cyclotron frequency for Ca_{++} is 15 Hz whereas the remaining frequencies are in the range 7 – 13 Hz (theta waves) at which also the most important Schumann resonances lie. The cyclotron frequency 5.5 Hz of iron is also a bio-active frequency and is the lower edge of theta region of EEG. Also lower frequencies resonant frequencies such as 2.4 (Iodium ion) are present. Even more remarkably, the pattern of data forces to conclude that the interaction occurs at quantum level. This conclusion is is dramatic conflict with the predictions of the standard quantum theory and with the standard view about space-time but consistent with the many-sheeted space-time concept of TGD.

A confession is in order: for years I erratically believed that the magnitude of the magnetic field assignable to the biological body is $B_E = .5$ Gauss, the nominal value of the Earth’s magnetic field. Probably I had made the calculational error at very early stage when taking Ca_{++} cyclotron frequency 15 Hz as a standard. I am grateful for Bulgarian physicist Rossen Kolarov for pointing to me that the precise magnitude of the magnetic field implying the observed 15 Hz cyclotron frequency for Ca_{++} is .2 Gauss and thus slightly smaller than the minimum value .3 Gauss of B_E . This value must be assigned to the magnetic body carrying dark matter rather than to the flux quanta of the Earth’s magnetic field. This field value corresponds roughly to the magnitude of B_E at distance $1.4R$, R the radius of Earth.

$B = .2$ Gauss would corresponds to a flux tube radius $L = \sqrt{5/2} \times L(169) \simeq 1.58L(169)$, which does not correspond to any p-adic length scale as such. $k = 168 = 2^3 \times 3 \times 7$ with $n = 5$ would predict the field strength correctly as $B_{end} = 2B_E/5$ and predict the radius of the flux tube to be $r = 25 \mu m$, size of a large neuron. However, $k = 169$ with flux $2h_5$ would be must more attractive option since it would give a direct connection with Earth’s magnetic field. Furthermore, the model for EEG forces to assume that also a field $B_{end}/2$ must be assumed and this gives the minimal flux h_5 . Note that $n = 5$ is the minimal value of n making possible universal topological quantum computation with Beraha number $B_n = 4\cos^2(\pi/n)$ equal to Golden Mean [K30].

The conclusion that the effect of ELF fields on brain represents quantum effects associated with the transitions of ions confined in magnetic field in the direction of axon carrying $B = 2B_E/5 = .2$ Gauss, is supported by the following observations.

1. The frequencies 15, 30, 45, 60, 75 Hz having effect on primates are multiples of the same basic frequency $f = 15$ Hz, which turns out to be the cyclotron frequency of Ca_{++} ion. That these frequencies come in multiples is a direct signature of quantum: in classical world only basic frequency $f = 15$ Hz should have effects (forcing ions to rotational motion around field lines with this frequency).
2. Even multiples of 15 Hz have a weak but non-vanishing effect. This can be understood as resulting from parity conservation for the simplest transitions induced by that part of

the interaction Hamiltonian which does not depend on the longitudinal coordinate of the axon. The reason is that odd and even values of n for harmonic oscillator states have opposite parities and the interaction hamiltonian describing the transition has odd parity. The simplest possibility is that these transitions occur in second via intermediate virtual intermediate state and correspond to second order in perturbation theory. This observation provides additional strong support for the hypothesis that quantum transitions are involved.

These observations are consistent with the following interpretation. Ions with charge Z , spin S and mass m in the external magnetic field behave quantum mechanically like harmonic oscillator with energies quantized as multiples of

$$\begin{aligned} E &= (n + \frac{1}{2})\omega_c + \frac{S_z}{S}\omega_L , \\ \omega_c &= \frac{ZeB}{m} , \quad (\hbar = 1, c = 1) , \\ \omega_L &= \frac{gS\omega_c}{4} . \end{aligned} \tag{4.1}$$

Here S and S_z denote total spin and its projection to the direction of the magnetic field. The contribution to energy coming from longitudinal motion has not been written explicitly. Here g is so called Lande factor which for free elementary fermions equals to $g = 2$. The experimental findings suggests strongly that external em field induces resonant transitions from between magnetic states. By the quantization of the magnetic flux, predicted by TGD also classically, the minimal size of the magnetic flux tube for the magnetic field of Earth is of order cell size. An attractive hypothesis is that the magnetic field in question is associated with axon and is parallel to it.

It must be emphasized that this vision is forced by hard experimental facts and is in dramatic contradiction with the standard physics view about brain. The wave functions of ions in magnetic field are confined in a region of size of order

$$r_n \sim \sqrt{n/eB} ,$$

which is of the order of cell size for $B = .2$ Gauss: macroscopic quantum state is in question. In fact, the value $.5 \times 10^{-4}$ Tesla for Earth's magnetic fields corresponds to the length scale $L(169) \simeq 4 \mu m$ rather precisely for minimal value of the magnetic flux quantized as $ZeBS = n2\pi$ obtained for $n = 1$ (S denotes the area of the flux tube) and $Z = 2e$. $L(169)$ seems to correspond to our sensory consciousness and various macroscopic quantum phases seem to reside at $k = 169$ space-time sheets probably forming join along boundaries condensates.

The binding energies of ions in Earth's magnetic field are extremely small: of order 10^{-14} eV, which is ridiculously small energy when compared with the natural energy scale of one eV and corresponds to a temperature of order 10^{-10} Kelvin. According to standard quantum physics, Earth's magnetic field should have absolutely no detectable effects in hot, wetty and noisy environment provided by brain. Many-sheeted space-time concept provides the solution to the riddle. Ions are not on the molecular space-time sheets but have dropped to the cellular space-time sheet and it is indeed very cold, dry and silent here: an ideal place for the formation of macroscopic quantum phases. The energy scale implies the upper bound $T < 10^{-10}$ Kelvin for the temperature at cellular space-time sheets.

A further empirical input of crucial importance were the observations challenging the cherished notions of ionic pumps and channels [I7]. These findings lead to a concrete view about biosystems as three-levelled structures involving massless extremals (MEs), super conducting magnetic flux tube structures, and atomic space-time sheets containing the ordinary matter. MEs control the dynamics of the superconducting ions inside magnetic flux tube structures. Magnetic flux tubes in turn are in a many-sheeted ionic flow equilibrium with the atomic space-time sheets and thus control the ionic concentrations at these space-time sheets.

This general framework leads to a rather detailed model for the generation of nerve pulse and EEG; to a model of sensory representations based on the notion of sensory canvas realized in terms of magnetic flux tube structures outside body with MEs serving as projectors of the cortical sensory representations to this sensory canvas; to a model of cognition including the realization of the memetic code in terms of cognitive antineutrinos and a physical mechanism translating nerve

pulse sequences to the 126 bit long codewords of the memetic code; and finally, to a model for the quantum correlates of the sensory qualia and to what deserves to be called spectroscopy of consciousness.

4.3.4 Electromagnetic selves

Rather remarkably, the time scale of .1 seconds predicted by the model of the memetic code and defining in the zero energy ontology a fundamental time scale of electron as well as the time scales of the photons associated with the magnetic transition frequencies, in particular cyclotron frequencies, of ions correspond to the time scale of EEG. The currents generating EEG certainly create weak electromagnetic radiation fields which in TGD framework correspond to topological field quanta of size of Earth: the lowest Schumann frequency is roughly $c/2\pi R$, R radius of Earth, and equal to $\omega \simeq 8$ Hz. It is known that EEG frequencies are in the same frequency range as so called Schumann frequencies 8, 14, 21, ... Hz [F1] associated with the resonances of the electromagnetic fields in the 80 km thick wave cavity between Earth surface and ionosphere.

The higher EEG frequencies seem to correlate with higher Schumann resonance frequencies: in particular, the frequencies 13 and 39 Hz which are also cyclotron resonance frequencies of Na_+ , are very near to Schumann frequencies. Schumann frequencies vary in time and it has been found that also the variations of EEG frequencies correlate with this variation. Magnetic perturbations near Schumann frequencies are known to have profound effects on human brain inducing altered states of consciousness and cortical instabilities such microseizures and epilepsies [J20]. The photons generated by Josephson currents associated with macroscopic ionic BE condensates have wavelengths of order Earth size and the topological field quanta representing classically the radiation field have size of Earth.

These observations suggests the identification of the relevant selves in our self-hierarchy are electromagnetic selves having the size of Earth and correspond to EEG frequencies. What happens is that Josephson currents generate classical ELF em fields represented by topological field quanta of this size (by uncertainty principle alone) which in turn couple resonantly to ions. These observations raise the question whether our “physical” body is only a tip of an iceberg and formed by the topological condensation of the biomatter around electromagnetic topological field quanta serving as templates for the biostructures [K6]. There is also neuropsychological evidence for the importance of ELF fields. In particular, the work of Michael Persinger is especially important [J22, J21, J27] [K16].

One possible scenario inspired by these observations is following.

1. The magnetic transition frequencies for the superconducting ions at the flux quanta of magnetic field $B=.2$ Gauss correspond to personal sensory consciousness. The magnetic flux tubes emanating more or less vertically from brain and accompanied by massless extremals could act as projectors defining personal sensory representations at the magnetic sensory canvas formed by the flux tubes (or possibly shell like topological quanta) of Earth’s magnetic field.
2. Schumann frequencies associated with the oscillations of the flux tubes of Earth’s magnetic field would in turn correspond to transpersonal aspect of consciousness. Schumann resonances could indeed induce a synchrony of the vertical magnetic flux tube structures associated with separate brains and even entangle them during sleep. This view is supported by some observations. In hypnagogic states (states between wake and sleep) EEG is peaked near the lowest Schumann frequency 7.8 Hz. During these states it is possible to experience hallucinations and identification experiences (I have now and then fleeting but completely “real” experiences of being someone else). The so called sleeping spindles correspond to EEG patterns at 14 Hz which is the second Schumann frequency. A possible interpretation is that during sleep collective consciousness begins to dominate and brains form a highly synchronous whole. It would be interesting to test whether there are correlations between EEGs of different persons during sleep.

4.4 Some Functions Of Magnetic Body

The magnetic bodies associated with various body parts, including cellular and even molecular magnetic bodies, could have several functions besides defining a hierarchy of intentional agents

(for this aspect see [K29]).

4.4.1 Topologically quantized classical fields as templates for the formation of bio-structures?

Magnetic bodies could serve as templates of bio-structures. For instance, blood circulation and central nervous system could have magnetic circuitries as templates. The web like structure formed by topological field quanta representing classical fields, in particular em fields, is reminiscent of structures formed by micro-tubuli and collagens forming the connective tissue of living systems. It has been already earlier suggested that magnetic flux tubes and other topological field quanta serve as templates for various bio-structures in the sense that ordinary matter is topologically condensed on the flux tube like structures. This would mean that living systems would be only part of much larger web formed by Earth's classical em field forming one particular sub-self (mental image!) of Mother Gaia.

The thickness for the flux tubes of Earth's magnetic field is about $2/\sqrt{eB} \simeq 4 \times 10^{-6}$ meters. There is direct evidence for the hypothesis that ions in a magnetic field $B_{end} = 2B_E/5 = .2$ Gauss, where $B_E = .5$ Gauss is the nominal value of the Earth's magnetic field, form quantum states with the characteristic energies of order 10^{-14} eV and size of the orbit being of order $2/\sqrt{eB}$, that is cell size. It must be emphasized that B_{end} is not equal to B_E as I erratically believed for a long time. The model for dark matter as macroscopic quantum phases with Planck constant equal to an integer multiple of the ordinary Planck constant [K13] leads to the working hypothesis that B_{end} corresponds to the dark counterpart of B_E [K11].

For $B_{end} = 2/5B_E = .2$ Gauss interpreted as a dark magnetic field with $\hbar = 5\hbar_0$ carrying 2 units of flux (the unit is $h_5 = 5h_0$) and corresponding also to the p-adic length scale $L(169)$, the radius is $25 \mu\text{m}$, the size of a large neuron. This possibly relates to the fact that the effects of ELF em fields are observed for vertebrates (for details see [K11]).

The coupling of the neuronal layers of cortex and perhaps all cells with the flux tubes of Earth's magnetic field could make possible entanglement between brain and Mother Gaia. If magnetic flux tubes of the dark counterpart of B_E have direct geometric coupling with brain one could perhaps understand the miraculous ability of birds and bees to navigate using Earth's magnetic field. The proteins navigating along micro-tubuli, cells navigating along collagen fibres and birds navigating along Earth's magnetic field lines would all be guided by higher level selves.

One could see also humans and the societies formed by them as continually self-organizing organs in the body of electromagnetic Mother Gaia. In this picture the narrow wave cavity of radius 80 km between Earth's surface and ionosphere could be like brain of Earth, which is very sensitive to the conditions of ionosphere and biosphere and has "biofeedback" coupling with living systems. The effect of oscillatory phenomena (sound, radiations and magnetic fields) at frequencies Schumann resonances on brain to be discussed below supports also the direct interaction of our brain with Mother Gaia via Earth's electromagnetic field.

It is interesting to notice that the ratio of the thickness of solar corona (10^6 m) to the radius of Sun (5×10^8 m), the height of the wave cavity of Earth (80 km) to Earth radius (7×10^6 m), the ratio of the thickness of grey matter of cortex (1 mm) to the size of human brain lobe (10 cm) as well as the ratio of the thickness of the cell membrane (10^{-8} m) to the radius of neuron (2.5×10^{-6}) have roughly the same value of order 10^{-2} . Could this mean that cell membrane, cortex, electromagnetic cavity of Earth and solar corona might have similar role in the self hierarchy? The general ideas about self-organization indeed support this view: boundary regions are subject to the most intense external energy feed and thus self-organize most effectively.

The web formed by topological field quanta of the classical em and fields continues to arbitrary long length scales. For instance, the flux tube structure of solar magnetic field provides an explanation for the anomalously high temperature of solar corona and a model for solar spot cycle [K27]. Perhaps also Sun is a conscious self forming part of "Indra's net" representing electromagnetic and other classical fields of cosmos. Since the four CP_2 coordinates are the primary dynamical variables, one must consider the possibility that topologically quantized classical gauge fields and classical gravitational field could form rather independent sub-selves.

4.4.2 Dark magnetic fields and living matter

A considerable sharpening of the above discussed speculative picture came with the development of TGD inspired vision about dark matter as macroscopic quantum phases with quantized value of Planck constant having arbitrarily large values coming as integer multiples of the ordinary Planck constant [K13].

Dark matter hierarchy leads to a detailed quantitative view about quantum biology with several testable predictions [K11] .

1. The most general hypothesis is allowed by the proposed generalization of the notion of imbedding space is that the values of $r = \hbar/hbar_0$ come as rationals [K13]. A less general alternative is that the values r of come as integers: $r = n$, where n characterizes the quantum phase $q = \exp(i\pi/n)$ characterizing Jones inclusion [K31]. In this case n would be a product of integers characterizing the number of sheets for singular coverings of CD and CP_2 .
2. The values of n for which quantum phase is expressible in terms of squared roots are number theoretically preferred and correspond to integers n expressible as $n = 2^k \prod_n F_{s_n}$, where $F_s = 2^{2^s} + 1$ is Fermat prime and each of them can appear only once. The lowest Fermat primes are $F_0 = 3, F_1 = 5, F_2 = 17$.

The prediction is that also rational or at least integer multiples of p-adic length scales are possible as preferred length scales. The unit of magnetic flux scales up as $h_0 \rightarrow h = rh_0$ in the transition scaling the Planck constant by r : one manner to achieve this is by scalings $L(k) \rightarrow rL(k)$ and $B \rightarrow B/r$.

$B = .2$ Gauss would corresponds to a flux tube radius $L = \sqrt{5/2} \times L(169) \simeq 1.58L(169)$, which does not correspond to any p-adic length scale as such. $k = 168 = 2^3 \times 3 \times 7$ with $n = 5$ would predict the field strength correctly as $B_{end} = 2B_E/5$ and predict the radius of the flux tube to be $r = 18 \mu\text{m}$, size of a large neuron. However, $k = 169$ with flux $2h_5$ would be must more attractive option since it would give a direct connection with Earth's magnetic field. Furthermore, the model for EEG forces to assume that also a field $B_{end}/2$ must be assumed and this gives the minimal flux h_5 . Note that $n = 5$ is the minimal value of n making possible universal topological quantum computation with Beraha number $B_n = 4\cos^2(\pi/n)$ equal to Golden Mean [K30].

An natural working hypothesis is that B_{end} defines the dark counterpart of the ordinary magnetosphere and that the relationship $B_{end} = 2B_E/5$ holds as a time average in the entire magnetosphere. The flux quanta of B_{end} would carry dark matter and would be responsible for the quantum control of the living matter.

4.4.3 Magnetic flux tubes and metabolism

Magnetic flux tubes could define super-conducting circuitry making possible a many-sheeted control of homeostasis: this aspect is discussed in [K17]. The hierarchy of magnetic flux tubes could also define many-sheeted lasers, and the dropping of particles to the larger space-time sheets would define a hierarchy of metabolic energy currencies as zero point kinetic energies liberated in the process. Process would also generate radiation at the harmonics of cyclotron frequencies at the larger space-time sheet. These frequencies could define a considerable part of EEG. Also fractally scaled up versions of EEG having similar band structure are predicted. The findings of Peter [I4, I5] are consistent with this prediction [K3]. The dropping of particles to larger space-time sheets for population inverted lasers would be also ideal for the realization of bio-control by time mirror mechanism and make possible remote metabolism and remote motor control.

4.4.4 Magnetic flux tubes as Nature's own bio-laboratory

Magnetic flux tubes could be ideal structures for the isolation and purification of various bio-molecules, and make also possible precise targeting of the reactants to reaction volumes defined by the nodes of the magnetic flux tube circuitry. Purification is made possible by the weight of the molecule if quantum-classical correspondence holds true in the sense that a magnetic flux tube carrying super-conducting bosons of mass m deforms so that it runs along a classical orbit of the particle with radius proportional to m . This would make sense for a many-sheeted magnetic field for which the fluxes associated with the magnetic flux tubes along which particles move return

along much larger space-time sheets and define the average magnetic field in which the particles move. This kind of Nature's own bio-laboratory might explain the miraculous selection of bio-molecules essential for the pre-biotic evolution. In accordance with the p-adic vision about the evolution of cognition, the evolution would have been proceeded from and guided by the magnetic flux tube structures of the Earth's magnetic field to the bio-chemical level [K14].

4.5 The Magnetic Fields Associated With Body Parts And Higher Levels Of Consciousness

The basic vision is that magnetic flux tubes containing ionic super-conductors, MEs carrying exotic representations of p-adic Super Virasoro algebra, and biological organisms live in a fractal symbiosis. MEs can induce cyclotron transitions amplified to quantum phase transitions inside magnetic flux tubes provided they have length above the wavelength defined by the cyclotron frequency. The exotic p-adic Super Virasoro representations with MEs have wavelength determined by the fundamental frequency which is of same order as the cyclotron frequency. The interaction of MEs and magnetic flux tubes by SQUID mechanism requires that magnetic flux of ME generates a current inside a circuit formed by magnetic flux tubes. Magnetic flux tubes to have arbitrary size scales below the size scale of ME.

Some body parts are carriers of static magnetic fields. The value of the static magnetic field associated with eye is slightly below 10^{-11} Tesla whereas the strength of Earth's magnetic field is about $.5 \times 10^{-4}$ Tesla. Also pineal gland ("third eye" also in a rather literal sense, see [K15]) contains magnetic material. Unfortunately I do not know the value of the corresponding dipole strength: for a dipole having size of order micrometer the maximal dipole strength would be very roughly 10^{-9} times corresponding dipole strength for Earth's magnetic field which would mean field of order 10^{-13} T. Also head and entire body could act as static magnetic dipoles.

For purely sensory consciousness .1 seconds is the characteristic time scale and EEG is closely related with this form of consciousness. In case of B_e the magnetic cyclotron frequencies are in the range obtained by scaling the range of cyclotron frequencies in Earth's magnetic field by a factor about 2×10^{-7} . This means that the periods of the ionic cyclotron frequencies are roughly in the range 12 hours-1.6 years for ionic cyclotron frequencies corresponding to the range of frequencies 90 – 0.1 Hz in Earth's magnetic field. These time scales are typical for the contents of higher level self consciousness involving self narrative. Notice however that these fields are perhaps not sufficiently weak for a self narrative in the time scale of several years.

The minimal thickness of the flux tubes for ULF selves associated with B_e would be roughly of the order of few millimeters, as one finds by scaling the radius for the flux tube of Earth's magnetic field which is about 5 microns.

Also bodily magnetic fields B_b could be involved. By scaling one obtains for the head's magnetic field an estimate $(mm/headsize)^2 B_e \sim 10^{-4} B_e$, which gives fT which is slightly above the thermal noise produced by body. The flux tube would have minimal thickness about 10 cm, the size scale of the head. The cyclotron frequency range would be scaled by a further factor of 10^4 factor meaning that the time scale range would be between 10 years and 10^4 years!

4.5.1 Higher levels of self hierarchy as levels of dark matter hierarchy

Higher levels of dark matter hierarchy provide neat quantitative view about self hierarchy and its evolution. The integer $n = 2^{k11}$, $k = 0, 1, 2, \dots$ seem to define favored values of Planck constant in living matter. This means a hierarchy in which time and length scales are zoomed up by a factor of 2048 in the transition to the next level of hierarchy. This integer represents also fundamental constant in TGD Universe [K27].

For instance, EEG time scales corresponds to $k = 4$ level of hierarchy and a time scale of .1 seconds [K10], and EEG frequencies correspond at this level dark photon energies above the thermal threshold so that thermal noise is not a problem anymore. Various levels of dark matter hierarchy would naturally correspond to higher levels in hierarchy of consciousness and the typical duration of life cycle would give an idea about the level in questions. $k = 7$ would correspond to a duration of moment of conscious of order human lifetime which suggests that $k = 7$ corresponds to the highest dark matter level relevant to our consciousness whereas higher levels would in general

correspond to transpersonal consciousness. $k = 5$ would correspond to time scale of short term memories measured in minutes and $k = 6$ to a time scale of memories measured in days.

The emergence of these levels must have meant evolutionary leap since long term memory is also accompanied by ability to anticipate future in the same time scale. This picture would suggest that the basic difference between us and our cousins is not at the level of genome as it is usually understood but at the level of the hierarchy of magnetic bodies [K19, K11]. In fact, higher levels of dark matter hierarchy motivate the introduction of the notions of super-genome and hyper-genome. The genomes of entire organ can join to form super-genome expressing genes coherently. Hyper-genomes would result from the fusion of genomes of different organisms and collective levels of consciousness would express themselves via hyper-genome and make possible social rules and moral.

4.5.2 Could the flux tubes of bodily magnetic fields correlate with more abstract levels of self consciousness?

The previous observations combined with the general speculative vision about Indra's web of consciousness stimulate several questions and ideas relating to the role of various magnetic fields associated with body.

1. Could it be that the ULF selves associated with the ionic super-conductors residing at the flux tubes of the bodily magnetic fields B_e and B_b (notice also the static magnetic fields of pineal gland and of other organs) belong to the self hierarchy and represent higher level selves contributing to our non-sensory consciousness under ordinary circumstances? This translates to the question whether the flux tubes of the corresponding topological quantized magnetic fields are closed in a relatively small volume as in case of an ideal dipole field or whether part of flux tubes have astrophysical lengths.
2. The above arguments do not pose restrictions on the strengths of the magnetic fields. In case of Earth's magnetic field the magnetic flux tubes have sizes of order of the wavelength associated with a typical cyclotron frequency. Could it be that the interacting MEs and magnetic flux tubes have sizes comparable to the wavelength defined by cyclotron frequency? If this is the case for B_e and B_b , the sizes of flux tubes would be astronomical with light day serving as lower bound. One could see the flux tubes of B_e and B_b as kind of umbilical cords connecting human bodies with magnetic structures of astronomical size and perhaps also with other organisms. Could one assign the more abstract levels of human consciousness and long term memories with the ULF selves associated with both the flux tubes of B_e and B_b and with MEs? In this view biological organisms would be like sensory-motor organs of this magnetic super organism.
3. Could one possibly test this hypothesis in case of B_e by studying the interaction of ULF em fields with frequencies above the time scale defined by day? Is the daily rhythm somehow relevant at the level of these em fields? For instance, could the natural 24 hour period certainly associated with ULF em fields of eye define the analog of alpha peak in EEG? Could the strength of the magnetic fields of eye be seen as a result of adaptation to the daily rhythm or is it dictated by the size of eye and flux quantization (there is roughly unit flux over an area of order millimeter squared)?

4.5.3 Objection

The bodily magnetic field change with time if the location orientation of the magnetic dipoles are fixed with body. Already the rotation of Earth induces periodic rotation of the magnetic flux tubes B_e and B_b . The volitional motion during wake-up period induces further effects.

There are several manners to circumvent this objection.

1. The most convincing manner to avoid the objection is that the flux tubes relevant for ULF consciousness have size at least of order of the wavelength defined by the cyclotron frequency and thus of the same order of magnitude as the size of the corresponding MEs. In this scale the rotating motion for the end of the magnetic flux tube of B_e or B_b would have absolutely

no significance and magnetic flux tubes would be somewhat like magnetic umbilic cords (like the tunnel involved with the NDE experiences connecting patient to the deceased relatives!).

2. If the magnetic flux tubes in question have sizes comparable or smaller than Earth size, the situation changes. Only in the very special case that the flux tubes rotate around Earth in the direction of equator, B_e and B_b could remain stationary and it makes sense to speak about stationary states.
3. One could also consider the possibility that magnetic flux quanta are layer like structures around Earth rather than rotating tubular structures, and have rotational symmetry with respect to the rotations around Earth axis so that it is body which is rotating with respect to these structures rather than these structures rotating with body. In this case it would make sense to assign cyclotron frequencies to the super-conducting ions in question since local magnetic states are certainly possible. In super-conductors of type I near critical temperature complicated layer like flux structures are indeed possible and in [K4, K5] it has been suggested that epithelial sheets formed by cell membrane inside cells correspond to this kind of flux structures.

The obvious question is how the rotation of Earth affects localized stationary states of the super-conducting ions inside co-rotating magnetic flux tubes with sizes smaller than Earth size. Does the description of the system in terms of cyclotron states make sense anymore? Quantum mechanically the ion in a stationary magnetic field is in radial degrees of freedom like a harmonic oscillator.

1. A simple analog system would be a harmonic oscillator rotating with an Earth and having an oscillation period which is longer than 12 hours. By separating center of mass degrees of freedom one finds that the particle in the rotating oscillator well feels besides the ordinary harmonic force a harmonic force $m\omega^2\bar{r}_{cm}$ which means that the complete solution to the equations of motion is superposition of the harmonic oscillator motion plus a periodic oscillatory term with the frequency of the external force. The average motion is therefore just the rotating harmonic oscillator motion.
2. In quantum case one has harmonic oscillator coupled to an external harmonic force having a frequency much larger than the oscillator frequency. Time dependent perturbation theory allows transitions only between the states whose energy difference $n\omega_0$ equals to the forcing frequency and transitions thus possible only if one has $\omega = n\omega_0$. Thus no quantum jumps would occur in the generic case.
3. The guess motivated by these considerations is that the magnetic state in a rotating magnetic field is in a good approximation obtained by applying time dependent rotation to the ordinary magnetic state and that in the time scale defined by the cyclotron frequency the average effects to the state cancel also now. Thus effective adiabaticity holds true.

4.5.4 Further questions related to vision

One can make several interesting questions related to vision and the magnetic fields of eye.

1. What is the role of the rapid eye movements during REM sleep, in particular during dreams? Could it be that the communication of long term memories from ULF level is involved with dreams and that the rhythmic eye movements are essential for establishing this communication?
2. The motor control associated with eyes is decoupled from the motor control of the remaining body. Therefore persons who are totally paralyzed can still move their eyes and can even communicate in this manner. Could the special role of the eye-motorics relate to the remaining ability to stay in contact with ULF selves associated with eyes?
3. What is the interpretation of the rays of light characterizing the visual perception of intense light. Perhaps there is some natural explanation for this but since I do not know about it, I can entertain myself with the idea that these rays could directly correspond to MEs

representing rays of light and connecting me with the objects of the external world. The correspondence between sensory experience and reality would be amazingly simple, if this is true.

4.5.5 NDE experiences and magnetic consciousness

NDE experiences [J28, J26] involve vision in an essential manner. This suggests that the dominating component of NDE consciousness could correspond to ULF selves associated with B_e and or B_b and give rise to the typical bird's eye of view about own body involved with the OBE and NDE experiences. The cyclotron frequency time scale associated with B_b would indeed fit with the life review experienced in NDE experiences. Body would be seen by ULF selves in bird's eye of view through the magnetic flux tubes of B_e and B_b . There would be a strange reciprocity resembling to the reciprocity encountered in the techniques of radio communications where the antennae sending messages can also serve as receiving antennae. NDE experiences involve also meeting of the dead relatives. Magnetic flux tubes can connect patient also to other organisms. and it would not be too surprising if magnetic flux tubes starting from the body could serve as an umbilic cord connecting the patient with living relatives or magnetic structures representing deceased relatives.

NDE experiences involve also the experience of travelling through a tunnel. The tunnel is experienced also during epilepsy and migraine, during meditation and relaxed state of mind, and with certain drugs like LSD, philocybin and mescaline.

I have also personal "tunnel experiences" every-daily: when I close my eyes in a half-meditative state achieved by writing at computer terminal, I can see a dim flow consisting of points. Typically this flow enters to or emergences from a tunnel. It can be rotating spiral like flow or simple sink or source. Source or sink can be also linear structure. The experience is not stable and tends to fade away all the time, and after few minutes I am not anymore able to achieve it. During my great experiences this flow was much more complicated and completely visible and formed a stable background of the ordinary visual experience and of hallucinatory visual images.

There is however no experience of entering into the tunnel in this case so that the tunnel need not be the same as encountered in NDEs. I have pondered quite a many times about the possible interpretation of this background flow. The basic observation was that it resembles liquid flow to a very high extent. Liquid flows are usually incompressible in an excellent approximation and this means that the velocity field is divergence free. This is the basic property of also magnetic fields and means that magnetic flux through a circuit moving along magnetic flux lines is conserved. This has stimulated the obvious guess that the background flow indeed represents magnetic field. The question which I have not made is whether this magnetic field resides inside my brain or outside it. In light of the above considerations the most natural answer to the question is that the magnetic field visualized by the flow is precisely where it seems to be. The flow would represent nothing but the magnetic field associated with my own eyes or more probably head, or rather how the self associated with the flux tubes of this magnetic field experiences the world.

The thickness of the flux tubes of B_b would be roughly the size of the head and this fits with idea that the tunnel experience represents directly the magnetic flow without any scaling factors involved. The fractality of TGD Universe suggests that these magnetic fields contain flux tubes of stronger magnetic fields inside them, so that the tunnel experience would represent the flux tubes of these magnetic fields experienced as sub-selves by the ULF self contributing to my visual consciousness in this altered state of consciousness. Of course, it might well be that also during the ordinary consciousness the experiencer is this magnetic ULF self and that sensory input dominates the content of the conscious experience and creates the illusion about body as self. In the absence of a sensory input the contents of consciousness of a clinically dead person is determined by these magnetic field and bird's eye of view about body results.

What remains after the physical death could therefore be determined by the magnetic fields involved with body. Magnetic flux conservation allows configurations of the closed magnetic flux loops containing ionic super-conductors as the counterpart of soul continuing existence after death. Wormhole magnetic fields and p-adic variants of these magnetic fields would also make it possible to store information about the magnetic fields originally associated with body. The overall view suggesting itself that our bodies are like sensors and motor organs of a gigantic electromagnetic organisms of astrophysical size and represent its sub-selves (mental images). This interpretation

conforms with the fact that in EMDR method rhythmic eye movements induce experiences involving the meeting of deceased relatives [J11].

The experimental study of what happens to the magnetic fields associated with eyes, head and other body parts after the physical death would obviously provide interesting information in this respect, perhaps one can someday even develop refined methods of communication with the deceased.

4.5.6 What about magnetic fields of heart?

The magnetic fields associated with eyes are not the only bodily magnetic fields with peak intensities higher than the non-static magnetic fields generated by brain. Heart generates a periodically oscillating magnetic field B_h of order $.5 \times 10^{-10}$ Tesla which is almost ten times higher than the static magnetic field generated by eyes. I do not know whether B_h contains a static component and if so, what is its strength. In any case, the absence of the static component means that the possibly super-conducting ions inside flux tubes of heart's magnetic field are in a periodically oscillating dipole field (most probably with respect to the geometric time!).

Also here my "great experience", which has turned out to be an extremely valuable repertoire of altered states of consciousness, provides an illustrative example. During the second great experience which lasted only one night, I experienced what might be called "heart consciousness". In the beginning of the experience my whole consciousness was filled by the rhythmic ".aqua-aqua-aqua.". It took some time to recognize that this rhythm was the rhythm of my own heart. Involved was also the mystical experience about the fundamental importance of water for life (said jokingly, heart is an organ specialized to deal with liquid!) and the precognition of the notion of infinite primes. Could it be that the MEs associated with heart dominated the contents of my consciousness during this experience.

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