Introduction

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Contents

1 Background

T(opological) G(eometro)D(ynamics) is one of the many attempts to find a unified description of basic interactions. The development of the basic ideas of TGD to a relatively stable form took time of about half decade [16]. The great challenge is to construct a mathematical theory around these physically very attractive ideas and I have devoted the last twenty-three years for the realization of this dream and this has resulted in seven online books [1, 2, 4, 5, 3, 6, 7] about TGD and eight online books about TGD inspired theory of consciousness and of quantum biology [10, 8, 9, 13, 11, 12, 14, 15].

Quantum T(opological)D(ynamics) as a classical spinor geometry for infinite-dimensional configuration space, p-adic numbers and quantum TGD, and TGD inspired theory of consciousness have been for last decade of the second millenium the basic three strongly interacting threads in the tapestry of quantum TGD.

For few yeas ago the discussions with Tony Smith generated a fourth thread which deserves the name 'TGD as a generalized number theory'. The work with Riemann hypothesis made time ripe for realization that the notion of infinite primes could provide, not only a reformulation, but a deep generalization of quantum TGD. This led to a thorough and extremely fruitful revision of the basic views about what the final form and physical content of quantum TGD might be.

The fifth thread came with the realization that by quantum classical correspondence TGD predicts an infinite hierarchy of macroscopic quantum systems with increasing sizes, that it is not at all clear whether standard quantum mechanics can accommodate this hierarchy, and that a dynamical quantized Planck constant might be necessary and certainly possible in TGD framework. The identification of hierarchy of Planck constants whose values TGD "predicts" in terms of dark matter hierarchy would be natural. This also led to a solution of a long standing puzzle: what is the proper interpretation of the predicted fractal hierarchy of long ranged classical electro-weak and color gauge fields. Quantum classical correspondences allows only single answer: there is infinite hierarchy of p-adically scaled up variants of standard model physics and for each of them also dark hierarchy. Thus TGD Universe would be fractal in very abstract and deep sense.

TGD forces the generalization of physics to a quantum theory of consciousness, and represent TGD as a generalized number theory vision leads naturally to the emergence of p-adic physics as physics of cognitive representations. The seven online books [1, 2, 4, 5, 3, 6, 7] about TGD and eight online books about TGD inspired theory of consciousness and of quantum biology [10, 8, 9, 13, 11, 12, 14, 15] are warmly recommended to the interested reader.

2 Basic Ideas of TGD

The basic physical picture behind TGD was formed as a fusion of two rather disparate approaches: namely TGD is as a Poincare invariant theory of gravitation and TGD as a generalization of the old-fashioned string model.

2.1 TGD as a Poincare invariant theory of gravitation

The first approach was born as an attempt to construct a Poincare invariant theory of gravitation. Space-time, rather than being an abstract manifold endowed with a pseudo-Riemannian structure, is regarded as a surface in the 8-dimensional space $H = M^4_+ \times CP_2$, where M^4_+ denotes the interior of the future light cone of the Minkowski space (to be referred as light cone in the sequel) and $CP_2 = SU(3)/U(2)$ is the complex projective space of two complex dimensions [17, 18, 19, 20]. The identification of the space-time as a submanifold [21, 22] of $M^4 \times CP_2$ leads to an exact Poincare invariance and solves the conceptual difficulties related to the definition of the energy-momentum in General Relativity [Misner-Thorne-Wheeler, Logunov *et al*]. The actual choice $H = M^4_+ \times CP_2$

implies the breaking of the Poincare invariance in the cosmological scales but only at the quantum level. It soon however turned out that submanifold geometry, being considerably richer in structure than the abstract manifold geometry, leads to a geometrization of all basic interactions. First, the geometrization of the elementary particle quantum numbers is achieved. The geometry of CP_2 explains electro-weak and color quantum numbers. The different H-chiralities of H-spinors correspond to the conserved baryon and lepton numbers. Secondly, the geometrization of the field concept results. The projections of the CP_2 spinor connection, Killing vector fields of CP_2 and of H-metric to four-surface define classical electro-weak, color gauge fields and metric in X^4.

2.2 TGD as a generalization of the hadronic string model

The second approach was based on the generalization of the mesonic string model describing mesons as strings with quarks attached to the ends of the string. In the 3-dimensional generalization 3-surfaces correspond to free particles and the boundaries of the 3- surface correspond to partons in the sense that the quantum numbers of the elementary particles reside on the boundaries. Various boundary topologies (number of handles) correspond to various fermion families so that one obtains an explanation for the known elementary particle quantum numbers. This approach leads also to a natural topological description of the particle reactions as topology changes: for instance, two-particle decay corresponds to a decay of a 3-surface to two disjoint 3-surfaces.

2.3 Fusion of the two approaches via a generalization of the space-time concept

The problem is that the two approaches seem to be mutually exclusive since the orbit of a particle like 3-surface defines 4-dimensional surface, which differs drastically from the topologically trivial macroscopic space-time of General Relativity. The unification of these approaches forces a considerable generalization of the conventional space-time concept. First, the topologically trivial 3-space of General Relativity is replaced with a "topological condensate" containing matter as particle like 3-surfaces "glued" to the topologically trivial background 3-space by connected sum operation. Secondly, the assumption about connectedness of the 3-space is given up. Besides the "topological condensate" there is "vapor phase" that is a "gas" of particle like 3-surfaces (counterpart of the "baby universes" of GRT) and the nonconservation of energy in GRT corresponds to the transfer of energy between the topological condensate and vapor phase.

3 The five threads in the development of quantum TGD

The development of TGD has involved four strongly interacting threads: physics as infinite-dimensional geometry; p-adic physics; TGD inspired theory of consciousness and TGD as a generalized number theory. In the following these five threads are briefly described.

3.1 Quantum TGD as configuration space spinor geometry

A turning point in the attempts to formulate a mathematical theory was reached after seven years from the birth of TGD. The great insight was "Do not quantize". The basic ingredients to the new approach have served as the basic philosophy for the attempt to construct Quantum TGD since then and are the following ones:

a) Quantum theory for extended particles is free(!), classical(!) field theory for a generalized Schrödinger amplitude in the configuration space CH consisting of all possible 3-surfaces in H. "All possible" means that surfaces with arbitrary many disjoint components and with arbitrary

internal topology and also singular surfaces topologically intermediate between two different manifold topologies are included. Particle reactions are identified as topology changes [23, 24, 25]. For instance, the decay of a 3-surface to two 3-surfaces corresponds to the decay $A \rightarrow B + C$. Classically this corresponds to a path of configuration space leading from 1-particle sector to 2-particle sector. At quantum level this corresponds to the dispersion of the generalized Schrödinger amplitude localized to 1-particle sector to two-particle sector. All coupling constants should result as predictions of the theory since no nonlinearities are introduced.

b) Configuration space is endowed with the metric and spinor structure so that one can define various metric related differential operators, say Dirac operator, appearing in the field equations of the theory.

3.2 p-Adic TGD

The p-adic thread emerged for roughly ten years ago as a dim hunch that p-adic numbers might be important for TGD. Experimentation with p-adic numbers led to the notion of canonical identification mapping reals to p-adics and vice versa. The breakthrough came with the successful p-adic mass calculations using p-adic thermodynamics for Super-Virasoro representations with the super-Kac-Moody algebra associated with a Lie-group containing standard model gauge group. Although the details of the calculations have varied from year to year, it was clear that p-adic physics reduces not only the ratio of proton and Planck mass, the great mystery number of physics, but all elementary particle mass scales, to number theory if one assumes that primes near prime powers of two are in a physically favored position. Why this is the case, became one of the key puzzless and led to a number of arguments with a common gist: evolution is present already at the elementary particle level and the primes allowed by the p-adic length scale hypothesis are the fittest ones.

It became very soon clear that p-adic topology is not something emerging in Planck length scale as often believed, but that there is an infinite hierarchy of p-adic physics characterized by p-adic length scales varying to even cosmological length scales. The idea about the connection of p-adics with cognition motivated already the first attempts to understand the role of the p-adics and inspired 'Universe as Computer' vision but time was not ripe to develop this idea to anything concrete (p-adic numbers are however in a central role in TGD inspired theory of consciousness). It became however obvious that the p-adic length scale hierarchy somehow corresponds to a hierarchy of intelligences and that p-adic prime serves as a kind of intelligence quotient. Ironically, the almost obvious idea about p-adic regions as cognitive regions of space-time providing cognitive representations for real regions had to wait for almost a decade for the access into my consciousness.

There were many interpretational and technical questions crying for a definite answer. What is the relationship of p-adic non-determinism to the classical non-determinism of the basic field equations of TGD? Are the p-adic space-time region genuinely p-adic or does p-adic topology only serve as an effective topology? If p-adic physics is direct image of real physics, how the mapping relating them is constructed so that it respects various symmetries? Is the basic physics p-adic or real (also real TGD seems to be free of divergences) or both? If it is both, how should one glue the physics in different number field together to get *The Physics*? Should one perform p-adicization also at the level of the configuration space of 3-surfaces? Certainly the p-adicization at the level of super-conformal representation is necessary for the p-adic mass calculations. Perhaps the most basic and most irritating technical problem was how to precisely define p-adic definite integral which is a crucial element of any variational principle based formulation of the field equations. Here the frustration was not due to the lack of solution but due to the too large number of solutions to the problem, a clear symptom for the sad fact that clever inventions rather than real discoveries might be in question.

Despite these frustrating uncertainties, the number of the applications of the poorly defined p-adic physics growed steadily and the applications turned out to be relatively stable so that it

was clear that the solution to these problems must exist. It became only gradually clear that the solution of the problems might require going down to a deeper level than that represented by reals and p-adics.

3.3 TGD as a generalization of physics to a theory consciousness

General coordinate invariance forces the identification of quantum jump as quantum jump between entire deterministic quantum histories rather than time=constant snapshots of single history. The new view about quantum jump forces a generalization of quantum measurement theory such that observer becomes part of the physical system. Thus a general theory of consciousness is unavoidable outcome. This theory is developed in detail in the books [10, 8, 9, 13, 11, 12, 14, 15].

3.3.1 Quantum jump as a moment of consciousness

The identification of quantum jump between deterministic quantum histories (configuration space spinor fields) as a moment of consciousness defines microscopic theory of consciousness. Quantum jump involves the steps

$$\Psi_i \rightarrow U\Psi_i \rightarrow \Psi_f \quad,$$

where U is informational "time development" operator, which is unitary like the S-matrix characterizing the unitary time evolution of quantum mechanics. U is however only formally analogous to Schrödinger time evolution of infinite duration although there is *no* real time evolution involved. It is not however clear whether one should regard U-matrix and S-matrix as two different things or not: U-matrix is a completely universal object characterizing the dynamics of evolution by self-organization whereas S-matrix is a highly context dependent concept in wave mechanics and in quantum field theories where it at least formally represents unitary time translation operator at the limit of an infinitely long interaction time. The S-matrix understood in the spirit of superstring models is however something very different and could correspond to U-matrix.

The requirement that quantum jump corresponds to a measurement in the sense of quantum field theories implies that each quantum jump involves localization in zero modes which parameterize also the possible choices of the quantization axes. Thus the selection of the quantization axes performed by the Cartesian outsider becomes now a part of quantum theory. Together these requirements imply that the final states of quantum jump correspond to quantum superpositions of space-time surfaces which are macroscopically equivalent. Hence the world of conscious experience looks classical. At least formally quantum jump can be interpreted also as a quantum computation in which matrix U represents unitary quantum computation which is however not identifiable as unitary translation in time direction and cannot be 'engineered'.

3.3.2 The notion of self

The concept of self is absolutely essential for the understanding of the macroscopic and macro-temporal aspects of consciousness. Self corresponds to a subsystem able to remain un-entangled under the sequential informational 'time evolutions' U. Exactly vanishing entanglement is practically impossible in ordinary quantum mechanics and it might be that 'vanishing entanglement' in the condition for self-property should be replaced with 'subcritical entanglement'. On the other hand, if space-time decomposes into p-adic and real regions, and if entanglement between regions representing physics in different number fields vanishes, space-time indeed decomposes into selves in a natural manner.

It is assumed that the experiences of the self after the last 'wake-up' sum up to single average experience. This means that subjective memory is identifiable as conscious, immediate short term memory. Selves form an infinite hierarchy with the entire Universe at the top. Self can be also

interpreted as mental images: our mental images are selves having mental images and also we represent mental images of a higher level self. A natural hypothesis is that self S experiences the experiences of its subselves as kind of abstracted experience: the experiences of subselves S_i are not experienced as such but represent kind of averages $\langle S_{ij} \rangle$ of sub-subselves S_{ij}. Entanglement between selves, most naturally realized by the formation of join along boundaries bonds between cognitive or material space-time sheets, provides a possible a mechanism for the fusion of selves to larger selves (for instance, the fusion of the mental images representing separate right and left visual fields to single visual field) and forms wholes from parts at the level of mental images.

3.3.3 Relationship to quantum measurement theory

The third basic element relates TGD inspired theory of consciousness to quantum measurement theory. The assumption that localization occurs in zero modes in each quantum jump implies that the world of conscious experience looks classical. It also implies the state function reduction of the standard quantum measurement theory as the following arguments demonstrate (it took incredibly long time to realize this almost obvious fact!).

a) The standard quantum measurement theory a la von Neumann involves the interaction of brain with the measurement apparatus. If this interaction corresponds to entanglement between microscopic degrees of freedom m with the macroscopic effectively classical degrees of freedom M characterizing the reading of the measurement apparatus coded to brain state, then the reduction of this entanglement in quantum jump reproduces standard quantum measurement theory provide the unitary time evolution operator U acts as flow in zero mode degrees of freedom and correlates completely some orthonormal basis of configuration space spinor fields in non-zero modes with the values of the zero modes. The flow property guarantees that the localization is consistent with unitarity: it also means 1-1 mapping of quantum state basis to classical variables (say, spin direction of the electron to its orbit in the external magnetic field).

b) Since zero modes represent classical information about the geometry of space-time surface (shape, size, classical Kähler field,...), they have interpretation as effectively classical degrees of freedom and are the TGD counterpart of the degrees of freedom M representing the reading of the measurement apparatus. The entanglement between quantum fluctuating non-zero modes and zero modes is the TGD counterpart for the $m - M$ entanglement. Therefore the localization in zero modes is equivalent with a quantum jump leading to a final state where the measurement apparatus gives a definite reading.

This simple prediction is of utmost theoretical importance since the black box of the quantum measurement theory is reduced to a fundamental quantum theory. This reduction is implied by the replacement of the notion of a point like particle with particle as a 3-surface. Also the infinite-dimensionality of the zero mode sector of the configuration space of 3-surfaces is absolutely essential. Therefore the reduction is a triumph for quantum TGD and favors TGD against string models.

Standard quantum measurement theory involves also the notion of state preparation which reduces to the notion of self measurement. Each localization in zero modes is followed by a cascade of self measurements leading to a product state. This process is obviously equivalent with the state preparation process. Self measurement is governed by the so called Negentropy Maximization Principle (NMP) stating that the information content of conscious experience is maximized. In the self measurement the density matrix of some subsystem of a given self localized in zero modes (after ordinary quantum measurement) is measured. The self measurement takes place for that subsystem of self for which the reduction of the entanglement entropy is maximal in the measurement. In p-adic context NMP can be regarded as the variational principle defining the dynamics of cognition. In real context self measurement could be seen as a repair mechanism allowing the system to fight against quantum thermalization by reducing the entanglement for the subsystem for which it is largest (fill the largest hole first in a leaking boat).

3.3.4 Selves self-organize

The fourth basic element is quantum theory of self-organization based on the identification of quantum jump as the basic step of self-organization [I1]. Quantum entanglement gives rise to the generation of long range order and the emergence of longer p-adic length scales corresponds to the emergence of larger and larger coherent dynamical units and generation of a slaving hierarchy. Energy (and quantum entanglement) feed implying entropy feed is a necessary prerequisite for quantum self-organization. Zero modes represent fundamental order parameters and localization in zero modes implies that the sequence of quantum jumps can be regarded as hopping in the zero modes so that Haken's classical theory of self organization applies almost as such. Spin glass analogy is a further important element: self-organization of self leads to some characteristic pattern selected by dissipation as some valley of the "energy" landscape.

Dissipation can be regarded as the ultimate Darwinian selector of both memes and genes. The mathematically ugly irreversible dissipative dynamics obtained by adding phenomenological dissipation terms to the reversible fundamental dynamical equations derivable from an action principle can be understood as a phenomenological description replacing in a well defined sense the series of reversible quantum histories with its envelope.

3.3.5 Classical non-determinism of Kähler action

The fifth basic element are the concepts of association sequence and cognitive space-time sheet. The huge vacuum degeneracy of the Kähler action suggests strongly that the absolute minimum space-time is not always unique. For instance, a sequence of bifurcations can occur so that a given space-time branch can be fixed only by selecting a finite number of 3-surfaces with time like(!) separations on the orbit of 3-surface. Quantum classical correspondence suggest an alternative formulation. Space-time surface decomposes into maximal deterministic regions and their temporal sequences have interpretation a space-time correlate for a sequence of quantum states defined by the initial (or final) states of quantum jumps. This is consistent with the fact that the variational principle selects preferred extremals of Kähler action as generalized Bohr orbits.

In the case that non-determinism is located to a finite time interval and is microscopic, this sequence of 3-surfaces has interpretation as a simulation of a classical history, a geometric correlate for contents of consciousness. When non-determinism has long lasting and macroscopic effect one can identify it as volitional non-determinism associated with our choices. Association sequences relate closely with the cognitive space-time sheets defined as space-time sheets having finite time duration and psychological time can be identified as a temporal center of mass coordinate of the cognitive space-time sheet. The gradual drift of the cognitive space-time sheets to the direction of future force by the geometry of the future light cone explains the arrow of psychological time.

3.3.6 p-Adic physics as physics of cognition and intentionality

The sixth basic element adds a physical theory of cognition to this vision. TGD space-time decomposes into regions obeying real and p-adic topologies labelled by primes $p = 2, 3, 5, ...$. p-Adic regions obey the same field equations as the real regions but are characterized by p-adic non-determinism since the functions having vanishing p-adic derivative are pseudo constants which are piecewise constant functions. Pseudo constants depend on a finite number of positive pinary digits of arguments just like numerical predictions of any theory always involve decimal cutoff. This means that p-adic space-time regions are obtained by gluing together regions for which integration constants are genuine constants. The natural interpretation of the p-adic regions is as cognitive representations of real physics. The freedom of imagination is due to the p-adic non-determinism. p-Adic regions perform mimicry and make possible for the Universe to form cognitive representations about itself. p-Adic physics space-time sheets serve also as correlates for intentional action.

A more more precise formulation of this vision requires a generalization of the number concept obtained by fusing reals and p-adic number fields along common rationals (in the case of algebraic extensions among common algebraic numbers). This picture is discussed in [E1]. The application this notion at the level of the imbedding space implies that imbedding space has a book like structure with various variants of the imbedding space glued together along common rationals (algebraics). The implication is that genuinely p-adic numbers (non-rationals) are strictly infinite as real numbers so that most points of p-adic space-time sheets are at real infinity, outside the cosmos, and that the projection to the real imbedding space is discrete set of rationals (algebraics). Hence cognition and intentionality are almost completely outside the real cosmos and touch it at a discrete set of points only.

This view implies also that purely local p-adic physics codes for the p-adic fractality characterizing long range real physics and provides an explanation for p-adic length scale hypothesis stating that the primes $p \simeq 2^k$, k integer are especially interesting. It also explains the long range correlations and short term chaos characterizing intentional behavior and explains why the physical realizations of cognition are always discrete (say in the case of numerical computations). Furthermore, a concrete quantum model for how intentions are transformed to actions emerges.

The discrete real projections of p-adic space-time sheets serve also space-time correlate for a logical thought. It is very natural to assign to p-adic pinary digits a p-valued logic but as such this kind of logic does not have any reasonable identification. p-Adic length scale hypothesis suggest that the $p = 2^k - n$ pinary digits represent a Boolean logic B^k with k elementary statements (the points of the k-element set in the set theoretic realization) with n taboos which are constrained to be identically true.

3.4 TGD as a generalized number theory

Quantum T(opological)D(ynamics) as a classical spinor geometry for infinite-dimensional configuration space, p-adic numbers and quantum TGD, and TGD inspired theory of consciousness, have been for last ten years the basic three strongly interacting threads in the tapestry of quantum TGD. For few yeas ago the discussions with Tony Smith generated a fourth thread which deserves the name 'TGD as a generalized number theory'. It relies on the notion of number theoretic compactifiction stating that space-time surfaces can be regarded either as hyper-quaternionic, and thus maximally associative, 4-surfaces in M^8 identifiable as space of hyper-octonions or as surfaces in $M^4 \times CP_2$ [E2].

The discovery of the hierarchy of infinite primes and their correspondence with a hierarchy defined by a repeatedly second quantized arithmetic quantum field theory gave a further boost for the speculations about TGD as a generalized number theory. The work with Riemann hypothesis led to further ideas.

After the realization that infinite primes can be mapped to polynomials representable as surfaces geometrically, it was clear how TGD might be formulated as a generalized number theory with infinite primes forming the bridge between classical and quantum such that real numbers, p-adic numbers, and various generalizations of p-adics emerge dynamically from algebraic physics as various completions of the algebraic extensions of rational (hyper-)quaternions and (hyper-)octonions. Complete algebraic, topological and dimensional democracy would characterize the theory.

What is especially satisfying is that p-adic and real regions of the space-time surface could emerge automatically as solutions of the field equations. In the space-time regions where the solutions of field equations give rise to in-admissible complex values of the imbedding space coordinates, p-adic solution can exist for some values of the p-adic prime. The characteristic non-determinism of the p-adic differential equations suggests strongly that p-adic regions correspond to 'mind stuff', the regions of space-time where cognitive representations reside. This interpretation implies that

p-adic physics is physics of cognition. Since Nature is probably extremely brilliant simulator of Nature, the natural idea is to study the p-adic physics of the cognitive representations to derive information about the real physics. This view encouraged by TGD inspired theory of consciousness clarifies difficult interpretational issues and provides a clear interpretation for the predictions of p-adic physics.

3.5 Dynamical quantized Planck constant and dark matter hierarchy

By quantum classical correspondence space-time sheets can be identified as quantum coherence regions. Hence the fact that they have all possible size scales more or less unavoidably implies that Planck constant must be quantized and have arbitrarily large values. If one accepts this then also the idea about dark matter as a macroscopic quantum phase characterized by an arbitrarily large value of Planck constant emerges naturally as does also the interpretation for the long ranged classical electro-weak and color fields predicted by TGD. Rather seldom the evolution of ideas follows simple linear logic, and this was the case also now. In any case, this vision represents the fifth, relatively new thread in the evolution of TGD and the ideas involved are still evolving.

3.5.1 Dark matter as large $\hbar$ phase

D. Da Rocha and Laurent Nottale [26] have proposed that Schrödinger equation with Planck constant $\hbar$ replaced with what might be called gravitational Planck constant $\hbar_{gr} = \frac{GmM}{v_0}$ ($\hbar = c = 1$). v_0 is a velocity parameter having the value $v_0 = 144.7 \pm .7$ km/s giving $v_0/c = 4.6 \times 10^{-4}$. This is rather near to the peak orbital velocity of stars in galactic halos. Also subharmonics and harmonics of v_0 seem to appear. The support for the hypothesis coming from empirical data is impressive.

Nottale and Da Rocha believe that their Schrödinger equation results from a fractal hydrodynamics. Many-sheeted space-time however suggests astrophysical systems are not only quantum systems at larger space-time sheets but correspond to a gigantic value of gravitational Planck constant. The gravitational (ordinary) Schrödinger equation would provide a solution of the black hole collapse (IR catastrophe) problem encountered at the classical level. The resolution of the problem inspired by TGD inspired theory of living matter is that it is the dark matter at larger space-time sheets which is quantum coherent in the required time scale [D6].

Already before learning about Nottale's paper I had proposed the possibility that Planck constant is quantized [E9] and the spectrum is given in terms of logarithms of Beraha numbers: the lowest Beraha number B_3 is completely exceptional in that it predicts infinite value of Planck constant. The inverse of the gravitational Planck constant could correspond a gravitational perturbation of this as $1/\hbar_{gr} = v_0/GMm$. The general philosophy would be that when the quantum system would become non-perturbative, a phase transition increasing the value of $\hbar$ occurs to preserve the perturbative character and at the transition $n = 4 \to 3$ only the small perturbative correction to $1/\hbar(3) = 0$ remains. This would apply to QCD and to atoms with $Z > 137$ as well.

TGD predicts correctly the value of the parameter v_0 assuming that cosmic strings and their decay remnants are responsible for the dark matter. The harmonics of v_0 can be understood as corresponding to perturbations replacing cosmic strings with their n-branched coverings so that tension becomes n^2-fold: much like the replacement of a closed orbit with an orbit closing only after n turns. $1/n$-sub-harmonic would result when a magnetic flux tube split into n disjoint magnetic flux tubes. Also a model for the formation of planetary system as a condensation of ordinary matter around quantum coherent dark matter emerges [D6].

3.5.2 Dark matter as a source of long ranged weak and color fields

Long ranged classical electro-weak and color gauge fields are unavoidable in TGD framework. The smallness of the parity breaking effects in hadronic, nuclear, and atomic length scales does not however seem to allow long ranged electro-weak gauge fields. The problem disappears if long range classical electro-weak gauge fields are identified as space-time correlates for massless gauge fields created by dark matter. Also scaled up variants of ordinary electro-weak particle spectra are possible. The identification explains chiral selection in living matter and unbroken $U(2)_{ew}$ invariance and free color in bio length scales become characteristics of living matter and of bio-chemistry and bio-nuclear physics. An attractive solution of the matter antimatter asymmetry is based on the identification of also antimatter as dark matter.

3.5.3 p-Adic and dark matter hierarchies and hierarchy of moments of consciousness

Dark matter hierarchy assigned to a spectrum of Planck constant having arbitrarily large values brings additional elements to the TGD inspired theory of consciousness.

a) Macroscopic quantum coherence can be understood since a particle with a given mass can in principle appear as arbitrarily large scaled up copies (Compton length scales as $\hbar$). The phase transition to this kind of phase implies that space-time sheets of particles overlap and this makes possible macroscopic quantum coherence.

b) The space-time sheets with large Planck constant can be in thermal equilibrium with ordinary ones without the loss of quantum coherence. For instance, the cyclotron energy scale associated with EEG turns out to be above thermal energy at room temperature for the level of dark matter hierarchy corresponding to magnetic flux quanta of the Earth's magnetic field with the size scale of Earth and a successful quantitative model for EEG results [M3].

Dark matter hierarchy leads to detailed quantitative view about quantum biology with several testable predictions [M3]. The applications to living matter suggests that the basic hierarchy corresponds to a hierarchy of Planck constants coming as $\hbar(k) = \lambda^k(p)\hbar_0$, $\lambda \simeq 2^{11}$ for $p = 2^{127-1}$, $k = 0, 1, 2, ...$ [M3]. Also integer valued sub-harmonics and integer valued sub-harmonics of λ might be possible. Each p-adic length scale corresponds to this kind of hierarchy and number theoretical arguments suggest a general formula for the allowed values of Planck constant λ depending logarithmically on p-adic prime [C6]. Also the value of $\hbar_0$ has spectrum characterized by Beraha numbers $B_n = 4cos^2(\pi/n)$, $n \geq 3$, varying by a factor in the range $n > 3$ [C6]. It must be however emphasized that the relation of this picture to the model of quantized gravitational Planck constant h_{gr} appearing in Nottale's model is not yet completely understood.

The general prediction is that Universe is a kind of inverted Mandelbrot fractal for which each bird's eye of view reveals new structures in long length and time scales representing scaled down copies of standard physics and their dark variants. These structures would correspond to higher levels in self hierarchy. This prediction is consistent with the belief that 75 per cent of matter in the universe is dark.

1. Living matter and dark matter

Living matter as ordinary matter quantum controlled by the dark matter hierarchy has turned out to be a particularly successful idea. The hypothesis has led to models for EEG predicting correctly the band structure and even individual resonance bands and also generalizing the notion of EEG [M3]. Also a generalization of the notion of genetic code emerges resolving the paradoxes related to the standard dogma [L2, M3]. A particularly fascinating implication is the possibility to identify great leaps in evolution as phase transitions in which new higher level of dark matter emerges [M3].

It seems safe to conclude that the dark matter hierarchy with levels labelled by the values of Planck constants explains the macroscopic and macro-temporal quantum coherence naturally.

That this explanation is consistent with the explanation based on spin glass degeneracy is suggested by following observations. First, the argument supporting spin glass degeneracy as an explanation of the macro-temporal quantum coherence does not involve the value of $\hbar$ at all. Secondly, the failure of the perturbation theory assumed to lead to the increase of Planck constant and formation of macroscopic quantum phases could be precisely due to the emergence of a large number of new degrees of freedom due to spin glass degeneracy. Thirdly, the phase transition increasing Planck constant has concrete topological interpretation in terms of many-sheeted space-time consistent with the spin glass degeneracy.

2. Dark matter hierarchy and the notion of self

The vision about dark matter hierarchy leads to a more refined view about self hierarchy and hierarchy of moments of consciousness [J6, M3]. The larger the value of Planck constant, the longer the subjectively experienced duration and the average geometric duration $T(k) \propto \lambda^k$ of the quantum jump.

Quantum jumps form also a hierarchy with respect to p-adic and dark hierarchies and the geometric durations of quantum jumps scale like $\hbar$. Dark matter hierarchy suggests also a slight modification of the notion of self. Each self involves a hierarchy of dark matter levels, and one is led to ask whether the highest level in this hierarchy corresponds to single quantum jump rather than a sequence of quantum jumps. The averaging of conscious experience over quantum jumps would occur only for sub-selves at lower levels of dark matter hierarchy and these mental images would be ordered, and single moment of consciousness would be experienced as a history of events. The quantum parallel dissipation at the lower levels would give rise to the experience of flow of time. For instance, hadron as a macro-temporal quantum system in the characteristic time scale of hadron is a dissipating system at quark and gluon level corresponding to shorter p-adic time scales. One can ask whether even entire life cycle could be regarded as a single quantum jump at the highest level so that consciousness would not be completely lost even during deep sleep. This would allow to understand why we seem to know directly that this biological body of mine existed yesterday.

The fact that we can remember phone numbers with 5 to 9 digits supports the view that self corresponds at the highest dark matter level to single moment of consciousness. Self would experience the average over the sequence of moments of consciousness associated with each sub-self but there would be no averaging over the separate mental images of this kind, be their parallel or serial. These mental images correspond to sub-selves having shorter wake-up periods than self and would be experienced as being time ordered. Hence the digits in the phone number are experienced as separate mental images and ordered with respect to experienced time.

3. The time span of long term memories as signature for the level of dark matter hierarchy

The simplest dimensional estimate gives for the average increment τ of geometric time in quantum jump $\tau \sim 10^4 \ CP_2$ times so that $2^{127} - 1 \sim 10^{38}$ quantum jumps are experienced during secondary p-adic time scale $T_2(k = 127) \simeq 0.1$ seconds which is the duration of physiological moment and predicted to be fundamental time scale of human consciousness [L1]. A more refined guess is that $\tau_p = \sqrt{p}\tau$ gives the dependence of the duration of quantum jump on p-adic prime p. By multi-p-fractality predicted by TGD and explaining p-adic length scale hypothesis, one expects that at least $p = 2$-adic level is also always present. For the higher levels of dark matter hierarchy τ_p is scaled up by $\hbar/\hbar_0$. One can understand evolutionary leaps as the emergence of higher levels at the level of individual organism making possible intentionality and memory in the time scale defined τ [L2].

Higher levels of dark matter hierarchy provide a neat quantitative view about self hierarchy and its evolution. For instance, EEG time scales corresponds to $k = 4$ level of hierarchy and a time scale of .1 seconds [J6], and EEG frequencies correspond at this level dark photon energies

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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 the hierarchy of consciousness and the typical duration of life cycle would give an idea about the level in question.

The level would determine also the time span of long term memories as discussed in [M3]. $k = 7$ 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 [L2, M3]. 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 Bird's eye of view about the topics of the book

The evolution of ideas about genetic code involves several threads: three models for genetic code have emerged during years. The models seem to be consistent with each other but do not imply each other.

4.1 Combinatorial hierarchy of codes

If I remember correctly, the idea about Combinatorial Hierarchy of codes containing genetic code as a special case emerged first. Combinatorial Hierarchy consists of Mersenne numbers $M(k+1) = M_{M(k)} = 2^{M(k)} - 1$, $M(1)) = 2$, proposed by Hilbert to form an infinite sequence of Mersenne primes. The interpretation of this hierarchy would be in terms of an abstraction hierarchy obtained by forming all Boolean statements about Boolean statements at a given level of hierarchy and throwing away one of them so that one statement would be a taboo whose negation cannot be even considered.

Quite recently it became clear that p-adic length scale hypothesis stating that p-adic primes $p \simeq 2^k$, k integer with primes preferred, could be also interpreted in terms of a Boolean logic with $p = 2^k - n$ statements resulting when n statements are taken as taboos. Mersenne primes would represent a situation with a minimal number of taboos/dogmas/axioms/beliefs. The recent view about the relationship between p-adic and real space-time sheets leads naturally to this interpretation [E1].

The model does not fix genetic code but is consistent with the dominating variant of the genetic code (for some rare variants 8 DNAs code for the same aminoacid whereas the model predicts that 6 DNAs is the maximum). The prediction is that memetic code with code words consisting of 126 bits analogous to the 6 bits of genetic code is the next code in the hierarchy. A sequence of 21 DNA triplets is enough to realize memetic codon. 2-bit code possibly represented by 4 DNA singlets would represent the lowest level of the hierarchy. Introns are good candidates for memetic codons being perhaps expressed as temporal or spatial electromagnetic field patterns. Nerve pulse patterns can be identified as a reduction of memetic code words of duration .1 seconds to genetic code words since the bits higher than sixth have durations below millisecond and cannot be represented in terms of nerve pulses.

4.2 The notion of many-sheeted DNA

Next came the notion of many-sheeted DNA with the basic idea being that DNA could represent in its topological structure directly the structures of body parts and that the field/magnetic body of DNA could serve as a template for the self-organization of the bio-matter.

Much later the discovery of the dark matter hierarchy led to a much more profound and detailed vision about the role of magnetic flux quanta. Magnetic flux sheets carrying magnetic fields with strength of dark companion $B_{end} = 2B_E/5 = .2$ Gauys or $B_{end}/2$ Earth's magnetic field B_E would define what might be seen as pages of book containing sequences of genomes from different cell nuclei as text lines. This implies the notions of super and hyper genome. Super genome codes for a coherent gene expression at the level of organs. In the case of hyper genome the text lines contain super genomes belonging to different organisms, not necessarily of same species. The difference between us and our cousins could be understood as being to an explosive evolution of the hyper genome made possible by the evolution of language and leading to a collective gene expression making possible also social and moral rules.

4.3 What crop circles have to do with the pre-biotic evolution and evolution of genetic code?

Few years ago I decided to consider the possibility that crop circles are not hoax and constructed a model for two very special crop circles known as Chilbolton and Crabwood crop circles. These crop circles suggest an interpretation as messages containing information about the biology of the alien life forms responsible for their construction utilizing remote quantum control mechanisms predicted by TGD inspired theory of consciousness. In particular, Crabwood circle allows interpretation as a representation of the genetic codes of the life forms. This thought experiment led to a second model of genetic code in which one assigns an entropy to the code and maximizes it.

The work with crop circles led also to a model of pre-biotic evolution including a model for how genetic code has evolved as a fusion of simpler doublet and singlet codes. The key observation was the almost exact A-G and T-C symmetries of the genetic code with respect to the last codon, which for some mysterious reason have not met the mind of any theoretical physicist familiar with the notion of spontaneous symmetry breaking. The model finds supports directly from the cross shaped structure of tRNA which would have resulted as the linear tRNAs associated with doublet and singlet codes fused together.

The craziest sounding element of the model was the hypothesis that pre-biotic evolution might have proceeded in the hot interior of Earth with the magnetic body of Earth serving as a kind of Mother Gaia's womb. This is of course complete nonsense from the point of view of standard model physics but dark matter hierarchy predicting what I call N-atoms having more or less same chemical properties as ordinary atoms but N-fold transition energies would make possible dark life forms surviving in hot temperatures of the Earth's interior and even in solar corona.

4.4 Does genetic code maximize a number theoretic negentropy?

The latest attempt to understand genetic code is the number theoretical model of genetic code based on a very simple accidental observation. The number of primes smaller than 64 is 18: together with 0 and 1 this makes 20, the number of aminoacids. This led to the idea that genetic code assigns to an integers $n \in 0, 63$ labelling DNA triplet an integer 0,1 or prime $p \leq 63$. The principle fixing this map would be minimization of number theoretic Shannon entropy which can have also negative values so that maximization of information content of the code would be in question. The p-adic thermodynamics for the partitions of the integer n labelling DNA triplets with Hamiltonian depending only the number of summands in the partition would naturally define the number theoretic negentropy. An intensive period of computer experimentation showed that

genetic code and its variants are indeed consistent with the proposed variational principle and that This does not however prove that the variational principle implies these codes as local maxima of negentropy. The model is consistent with the model for the evolution of the genetic code as a fusion of doublet and singlet codes and with with the model based on Combinatorial Hierarchy.

Note that the maximization of negentropy of genetic code is highly analogous to the Negentropy Maximization Principle (NMP,[H2]) constraining the dynamics of quantum jumps. NMP states that the reduction of entanglement entropy (number theoretic negentropy for rational and even algebraic entanglement probabilities) is maximal in a given quantum jump.

The seven online books about TGD [1, 2, 4, 5, 3, 6, 7] and eight online books about TGD inspired theory of consciousness and quantum biology [10, 8, 9, 13, 11, 12, 14, 15] are warmly recommended for the reader willing to get overall view about what is involved.

5 The contents of the book

5.1 PART I: Some Physical and Mathematical Background

5.1.1 About the new physics behind quantum biology

This chapter was originally about the new physics behind qualia. The model of qualia indeed involves a lot of new physics: many-sheeted space-time; massless extremals; exotic Super Virasoro representations associated with discrete qualia; magnetic and cyclotron phase transitions associated with quantum critical quantum spin glass phases of exotic super conductors at cellular space-time sheets; classical color and electro-weak gauge fields in macroscopic length scales, to name the most important ingredients. Gradually the chapter however expanded so that it touches practically all new physics possibly relevant to TGD inspired quantum biology. Various physical mechanisms are discussed in exploratory spirit rather than restricting the consideration to those ideas which seem to be the final word about quantum biology or qualia just at this moment.

5.1.2 Topological Quantum Computation in TGD Universe

Topological quantum computation (TQC) is one of the most promising approaches to quantum computation. The coding of logical qubits to the entanglement of topological quantum numbers promises to solve the de-coherence problem whereas the S-matrices of topological field theories (modular functors) providing unitary representations for braids provide a realization of quantum computer programs with gates represented as simple braiding operations. Because of their effective 2-dimensionality anyon systems are the best candidates for realizing the representations of braid groups.

TGD allows several new insights related to quantum computation. TGD predicts new information measures as number theoretical negative valued entanglement entropies defined for systems having extended rational entanglement and characterizes bound state entanglement as bound state entanglement. Negentropy Maximization Principle and p-adic length scale hierarchy of space-time sheets encourage to believe that Universe itself might do its best to resolve the de-coherence problem. The new view about quantum jump suggests strongly the notion of quantum parallel dissipation so that thermalization in shorter length scales would guarantee coherence in longer length scales. The possibility of negative energies and communications to geometric future in turn might trivialize the problems caused by long computation times: computation could be iterated again and again by turning the computer on in the geometric past and TGD inspired theory of consciousness predicts that something like this occurs routinely in living matter.

The absolute minimization of Kähler action is the basic variational principle of classical TGD and predicts extremely complex but non-chaotic magnetic flux tube structures, which can get knotted and linked. The dimension of CP_2 projection for these structures is $D = 3$. These

structures are the corner stone of TGD inspired theory of living matter and provide the braid structures needed by TQC.

Anyons are the key actors of TQC and TGD leads to detailed model of anyons as systems consisting of track of a periodically moving charged particle realized as a flux tube containing the particle inside it. This track would be a space-time correlate for the outcome of dissipative processes producing the asymptotic self-organization pattern. These tracks in general carry vacuum Kähler charge which is topologized when the CP_2 projection of space-time sheet is $D = 3$. This explains charge fractionization predicted to occur also for other charged particles. When a system approaches chaos periodic orbits become slightly aperiodic and the correlate is flux tube which rotates N times before closing. This gives rise to Z_N valued topological quantum number crucial for TQC using anyons ($N = 4$ holds true in this case). Non-Abelian anyons are needed by TQC, and the existence of long range classical electro-weak fields predicted by TGD is an essential prerequisite of non-Abelianity.

Negative energies and zero energy states are of crucial importance of TQC in TGD. The possibility of phase conjugation for fermions would resolve the puzzle of matter-antimatter asymmetry in an elegant manner. Anti-fermions would be present but have negative energies. Quite generally, it is possible to interpret scattering as a creation of pair of positive and negative energy states, the latter representing the final state. One can characterize precisely the deviations of this Eastern world view with respect to the Western world view assuming an objective reality with a positive definite energy and understand why the Western illusion apparently works. In the case of TQC the initial *resp.* final state of braided anyon system would correspond to positive *resp.* negative energy state.

The light-like boundaries of magnetic flux tubes are ideal for TQC. The point is that 3-dimensional light-like quantum states can be interpreted as representations for the time evolution of a two-dimensional system and thus represented self-reflective states being "about something". The light-likeness (no geometric time flow) is a space-time correlate for the ceasing of subjective time flow during macro-temporal quantum coherence. The S-matrices of TQC can be coded to these light-like states such that each elementary braid operation corresponds to positive energy anyons near the boundary of the magnetic flux tube A and negative energy anyons with opposite topological charges residing near the boundary of flux tube B and connected by braided threads representing the quantum gate. Light-like boundaries also force Chern-Simons action as the only possible general coordinate invariant action since the vanishing of the metric determinant does not allow any other candidate. Chern-Simons action indeed defines the modular functor for braid coding for a TQC program.

5.2 PART II: PART II: Physical models for genome and evolution of genetic code

5.2.1 Genes and memes

In this chapter the basic TGD inspired ideas about genetic code are discussed.

1. Genetic and memetic code from the model of abstraction process

The basic numbers of genetic code are probably not accidental. This led for more than ten years ago to an attempt to construct a model for abstraction process reproducing the basic numbers of the genetic code. The simplest model for an abstraction process is based on a repeated formation of statements about statements starting from two basic statements. If one drops at each step of the construction the statement corresponding to empty set in the set theoretic realization of Boolean algebra, one obtains a hierarchy allowing to understand the basic numbers of genetic code, including the number of amino-acids. What one obtains is so called Combinatorial Hierarchy consisting of the Mersenne numbers $2, M(1) = 3, 7, 127, 2^{127} - 1, ..$ constructed using the rule $M(n+1) = M_{M(n)} = 2^{M(n)} - 1$. The explicitly listed ones are known to be primes. Combinatorial

Hierarchy emerges from a model of abstraction process as subsequent transitions from level to meta level by forming Boolean statements about Boolean statements of level n and dropping one statement away.

The infinite hierarchy of possible genetic codes suggests the possibility of an infinite hierarchy of increasingly complex life-forms. The natural question is whether a counterpart of the genetic code could make sense for our ideas, memes. Combinatorial Hierarchy model for abstraction process predicts that memetic code should correspond to the level M_{127} of the hierarchy. This leads to a precise realization of the memetic code in terms of binary sequences. Codewords, counterparts of mRNA, correspond to 126-bit sequences. Also almost-127-bit code with $2^{127} - 1$ codons is possible.

2. Frequency and pulse representations of codes

p-Adic length scale hypothesis and identification of codes as special cases of a hierarchy of p-adic cognitive codes allows quantitative predictions. The most general assumption assigns to any prime $p \simeq 2^k$, k integer, a hierarchy of cognitive codes with codeword having a duration equal to n-ary p-adic time scale $T_p(n)$ such that the number of bits is factor k_1 of k. Codewords could be realized either as k_1 harmonics of the fundamental frequency $f_p(n) = 1/T_p(n)$ or as temporal sequences of bits of duration $\tau = T_p(n)/k_1$ represented as pulses of maximal duration τ. Pulse-frequency dichotomy corresponds to dichotomies like particle-wave, nerve pulse-EEG, and talking left brain-singing right brain.

Genetic code would correspond to $k = 2^7 - 1 = 127$ and have 6 bits (64 DNA triplets). These codewords could be realized dynamically as temporal field patterns. For genetic code primes $p \simeq 2^k$, $k = 6 \times n$ define candidates for the duration of the genetic code word if all factors of k are assumed to define a possible number of bits of the code word. The time scales come as powers of 8 so that they cover the entire range of biologically relevant time scales down to CP_2 length scale, and genetic code could appear as fractally scaled versions unlike memetic code and perhaps also outside the biological context. $k = 2 \times 126 = 2 \times 6 \times 21 = 252$ allows the representation of both 126-bit memetic codeword, 6-bit genetic codeword, and almost-7-bit genetic code word. For pulse representation genetic codon would have a duration of 50 ms whereas the bit would have duration of 8.3 ms so that the realization using nerve pulse patterns is in principle possible. Frequency representation would be realized as 6 first harmonics of the fundamental frequency $f_1 = 2^n \times 20$ Hz, where $f_1 = 20$ Hz defines the lower end of audible frequency range and also the rate for the translation of mRNA triplets to amino-acids. 126-bit memetic code allows a representation as sequence of 21 nerve pulses of duration 2.4 ms each of them accompanied by 6-bit genetic codon realized at the microtubular level (this representation of genetic code has been suggested by Koruga).

The secondary p-adic time scale associated with M_{127} is .1 seconds and defines the duration of the almost 127-bit memetic codeword. For frequency representation is realized as 127 first harmonics of $f_1 = 10$ Hz and the duration of the bit for pulse representation is .8 ms which is shorter than the duration of nerve pulse. The duration .1 seconds of code word might be identified as the minimal duration of cortical mental images, and the so called features introduced by Walter Freeman could define pulse representation of memetic code words of 127 bits. The highest frequency in the frequency representation is 1270 Hz and could define the frequency responsible for synchronous neuronal firing known to be about 1 kHz. Various numerical co-incidences suggest that language corresponds to a particular realization of memetic and genetic codes closely related to their realization at DNA level.

3. Model for the evolution of genetic code from the symmetries of the code

TGD leads to a model for the evolution of the genetic code motivated by the observation that the genetic code possesses an exact A-G and almost exact T-C permutation symmetry with respect to the third nucleotide of the DNA triplet. This leads to the hypothesis that genetic code has evolved as a fusion of doublet and singlet codes accompanied by a small breaking of the product symmetry. The hypothesis is highly predictive, and it is possible to reproduce genetic code and

its variants by this mechanism in a natural manner. The mechanism has deep implications for the models of the bio-chemical evolution before genetic code: in particular a detailed model for the evolution of genetic code and pre-biotic evolution emerges.

4. Mapping memetic code to 169-bit micro-tubular code

169-bit micro-tubular code words is excellent candidate for a representation of long term memories as a temporal list of activated memes. The model for the mapping of memetic code to 169-bit microtubular code is dictated by the general ideas about realization of intentions and p-adic cognitive codes. When combined with general number theoretical arguments and physical considerations the model becomes highly unique. The prediction for the intronic representation of the memetic codon involving 9 DNA triplets as parity bits is readily testable, and also the prediction for the microtubular electric field pattern is in principle testable.

5. Genes, memes, and universal language

Also static representations of the memetic code are possible and intronic DNA could provide representation of memetic codewords as sequences of 21 DNA triplets. At DNA level memes and genes should relate like computer software and hardware. In the case of language the rules producing a given linguistic expression can be seen as the high level software, main programs, whereas words can be seen as hardware-like lower level subprograms. This leads to the idea that memetic codewords define the basic program modules producing linguistic expressions by activating genes which express themselves in terms of field patterns generating nerv pulse patterns generating words or word sequences very much analogous to proteins.

Time mirror mechanism and the structure of the computer language LISP inspire a concrete model for memes as intronic programs initiated from magnetic body and calling genes as subprograms in turn calling other genes as subprograms and generating at the lowest level field patterns generating nerve pulses patterns giving rise to the motor action producing speech. Phonemes could directly correspond to DNA triplets and define the basic building blocks of language having as such no meaning. If this view is correct, the development of spoken and written language would mean basically the emergence of a higher level of intentionality, which utilizes an already existing repertoire of memes expressed in many other manners. This would in turn suggest that animals and even plants possess some kind of languages realized at cellular level, and that even inter-species communications using common memetic grammar and genetic vocabulary.

6. Corals and men

A strong support for the idea of interspecies communications come from the sensational finding that the genome of corals, known to be the most primitive animals having nervous system, share a large number of common genes with vertebrates whereas they share much less common genes with flies and worms. This finding challenges profoundly the existing view about the evolution of animals and adds a further mystery to the halo of mysteries surrounding Cambrian explosion.

Since corals are usually regarded as relatively simple creatures, the most obvious questions concern the function of the complex genome. The TGD inspired answer is that the common genes provide a common vocabulary making possible communications between corals and vertebrates such as fishes. The genes express themselves in terms of electromagnetic field patterns and cyclotron transitions of Ca_{++} ions giving rise to primitive EEG are crucially involved. The calcium containing skeleton possessed by both corals and vertebrates could amplify the field patterns representing genes and make possible interspecies communications.

Coral reefs can be also seen as super organisms with cells replaced by double cell layers forming the corals. This forces to consider the possibility that coral reefs are super-organisms perhaps even possessing super-neural system consisting of super-neurons defined by differentiated corals. Accordingly, in TGD Universe coral reefs could be seen as descendants of higher level intra-terrestrial life forms which boosted Cambrian explosion by horizontal transfer of genes to much simpler life forms and providing also them with a nervous system.

7. Does ontogeny recapitulate also the future phylogeny at the level of genes and memes?

Ontogeny recapitulates phylogeny means that the morphogenesis of the embryo repeats the evolutionary steps leading to the organism. One might ask whether and how this process is realized at the level of genes and memes (introns expressing themselves electromagnetically): this could provide further understanding of the mysterious "junk DNA". Combining this question with some recent puzzling findings leads to a rather radical revision of the view about evolution proceeding through random mutations.

1. The second strange finding besides coral genome reported in New Scientist (5 June, 2004) was that the removal of large portions of conserved intronic DNA from mice has no detectable effects on the basic biological functions. Conserved parts of DNA are usually thought as being an outcome of a long selection process and far from genetic trash. This could be understood if the conserved introns have been radiated from corals and the selection process has occurred already before the Cambrian explosion induced by the emergence of the corals and leading to the sudden emergence of new highly developed life forms. That mouse introns did not have any identifiable function could mean that they are still waiting for time to become ripe for their expression.

2. A third strange discovery relates to morphogenesis and is known as Ciba Geigy effect. Chemists Guido Ebner and Guido Schuerch exposed germs, seeds, and eggs to an electric field with strength in the range .5-2 kV/m. For instance, the resulting trouts appeared to resemble their ancient predecessors. The leaves of certain plants represented a series of snapshots from evolution with the oldest leaves dating back to 300 million years. This suggests that the memone and genome represent ontogeny recapitulates phylogeny principle quite concretely, and that static electric fields could provide the practical manner to activate and study the ancient morphologies. Even partial transmutation of life forms to each other might be possible (beautiful swan to ugly duckling at least!). The activation of morphologies not yet realized is probably more difficult: new memetic programs require new genetic hardware.

The resulting vision about evolution of higher organisms would be as the activation of conserved memes and genes basically inherited from corals rather than by the emergence of new genes by random mutations. Very much like learning new features of a text processing program. The explosive evolution of human civilization could correspond to a rapid shift of the activated portion of memone and genome. The fact that 95 per cent of our DNA consists of introns suggests that an enormous evolutionary potential exists also at the level of personal evolution during single life cycle. TGD view about space-time as a 4-dimensional living organism would mean that this personal evolution continues after the biological death since the 4-body of geometric past does not disappear in the biological death.

5.2.2 Many-sheeted DNA

The problems of how genes code information about the morphology of organism and how this information is expressed, belong to the great puzzles of the developmental biology. A closely related mystery is the differentiation of cells. The notion of the genetic program is far from precise and it is not clear how close the analogy with a computer program is. There are also several problems which challenge the basic dogmas of genetics.

1. Only 1 per cent of DNA of human genome actually codes polypeptides. Eukaryote genes contain intron sequences which are transcribed into hnRNA but snipped of when hnRNA is transformed mRNA in process called slicing. The higher the evolutionary level of organism, the higher the fraction of introns is. Molecular Darwinistis see introns as "junk DNA" but there is evidence that introns are far from junk. For instance, the splicing of intron contribution from hnRNA to give mRNA can give several different outcomes depending on

the stage of development of the organism and introns are crucial for the effectiveness of immune system. Hence one can wonder whether intronic mRNA and protein mRNA could both form the real output of gene subprograms serving in some sense as input for other gene subprograms. This interpretation obviously conflicts with "gene-single protein" dogma in its basic form.

2. There are large amounts of highly repetitive DNA which is silent. One can wonder whether there is some fundamental mis-understanding involved. Could it be that this DNA is analogous to control DNA not transcribed to RNA and therefore not all useless. There is also active repetitive DNA.

3. There is large amount of silent DNA in control sections between genes. Could it be that this silent DNA expresses itself in some nonchemical manner? Chemical expression is very slow, translation rate being twenty aminoacids per second, and one can wonder whether life might have invented faster modes of gene expression and control of gene expression.

4. Plant genome is often by a factor of hundred longer than human genome. One could argue that the complexity of organism is measured by the length of the shortest program coding the organism. It is however not at all obvious how the genome of plants could be more reduntant than human genome since repetitive sequences common to all animals are present. Introns are in fact more frequent in human genome. This suggests that some new unidentified degrees of freedom giving rise to complexity might be present and that the chemistry of DNA in the sense of standard physics is perhaps not all that is needed to understand genetic program.

5. Various self-organization process such as self-assembly and de-assembly are very frequent in living systems. The problem how genes give rise to morphology of the organism is poorly understood. This forces to challenge the dogma of genetic determinism. One should be able to understand what is determined by genes and what is determined by self-organization and whether the genes of the standard physics are enough.

The reason why the above mentioned problems have turned out to be so untractable might be due to a wrong view about space-time. Many-sheeted space-time concept of TGD might be absolutely crucial for the expression of genetic code. Gene itself might be many-sheeted space-time structure coding faithfully the topology of the expression domain of gene. This many-sheeted structure of DNA could allow to understand the miraculous looking features of DNA replication and cell differentiation. TGD based view of evolution as p-adic evolution implied by the basic quantum theory, should be a crucial element of the picture. Together with p-adic length scale hypothesis, with Combinatorial Hierarchy model for genetic code allowing to interpret genes as Boolean statements, and general vision about quantum control and coordination based on a hierarchy of weakly coupled super conductors, the notion of many-sheeted DNA leads to precise quantitative predictions and a general model for genetic program. In particular, one can understand the mystery of introns. What interesting from the point of view of our consciousness is that it might be possible to interpret the Boolean statements represented by the exon and intron parts of genes as a physical representation for our belief system. Thus genes would code both matter– and mind like hardware of the living system.

5.2.3 DNA as Topological Quantum Computer

This chapter represents a vision about how DNA might act as a topological quantum computer (tqc). Tqc means that the braidings of braid strands define tqc programs and M-matrix (generalization of S-matrix in zero energy ontology) defining the entanglement between states assignable to the end points of strands define the tqc usually coded as unitary time evolution for Schrödinger equation. One can ends up to the model in the following manner.

1. Darwinian selection for which the standard theory of self-organization provides a model, should apply also to tqc programs. Tqc programs should correspond to asymptotic self-organization patterns selected by dissipation in the presence of metabolic energy feed. The spatial and temporal pattern of the metabolic energy feed characterizes the tqc program - or equivalently - sub-program call.

2. Since braiding characterizes the tqc program, the self-organization pattern should correspond to a hydrodynamical flow or a pattern of magnetic field inducing the braiding. Braid strands must correspond to magnetic flux tubes of the magnetic body of DNA. If each nucleotide is transversal magnetic dipole it gives rise to transversal flux tubes, which can also connect to the genome of another cell. As a matter fact, the flux tubes would correspond to what I call wormhole magnetic fields having pairs of space-time sheets carrying opposite magnetic fluxes.

3. The output of tqc sub-program is probability distribution for the outcomes of state function reduction so that the sub-program must be repeated very many times. It is represented as four-dimensional patterns for various rates (chemical rates, nerve pulse patterns, EEG power distributions,...) having also identification as temporal densities of zero energy states in various scales. By the fractality of TGD Universe there is a hierarchy of tqcs corresponding to p-adic and dark matter hierarchies. Programs (space-time sheets defining coherence regions) call programs in shorter scale. If the self-organizing system has a periodic behavior each tqc module defines a large number of almost copies of itself asymptotically. Generalized EEG could naturally define this periodic pattern and each period of EEG would correspond to an initiation and halting of tqc. This brings in mind the periodically occurring sol-gel phase transition inside cell near the cell membrane. There is also a connection with hologram idea: EEG rhythm corresponds to reference wave and nerve pulse patters to the wave carrying the information and interfering with the reference wave.

4. Fluid flow must induce the braiding which requires that the ends of braid strands must be anchored to the fluid flow. Recalling that lipid mono-layers of the cell membrane are liquid crystals and lipids of interior mono-layer have hydrophilic ends pointing towards cell interior, it is easy to guess that DNA nucleotides are connected to lipids by magnetic flux tubes and hydrophilic lipid ends are stuck to the flow.

5. The topology of the braid traversing cell membrane cannot be affected by the hydrodynamical flow. Hence braid strands must be split during tqc. This also induces the desired magnetic isolation from the environment. Halting of tqc reconnects them and make possible the communication of the outcome of tqc.

There are several problems related to the details of the realization.

1. How nucleotides A,T,C,G are coded to the strand color and what this color corresponds to physically? There are two options which could be characterized as fermionic and bosonic.

   i) Magnetic flux tubes having quark and anti-quark at their ends with u,d and u_c, d_c coding for A,G and T,C. CP conjugation would correspond to conjugation for DNA nucleotides.

   ii) Wormhole magnetic flux tubes having wormhole contact and its CP conjugate at its ends with wormhole contact carrying quark and anti-quark at its throats. The latter are predicted to appear in all length scales in TGD Universe.

2. How to split the braid strands in a controlled manner? High T_c super conductivity provides a possible mechanism: braid strand can be split only if the supra current flowing through it vanishes. A suitable voltage pulse induces the supra-current and its negative cancels it. The conformation of the lipid controls whether it it can follow the flow or not.

3. How magnetic flux tubes can be cut without breaking the conservation of the magnetic flux? The notion of wormhole magnetic field could save the situation now: after the splitting the flux returns back along the second space-time sheet of wormhole magnetic field. An alternative solution is based on reconnection of flux tubes. Since only flux tubes of same color can reconnect this process can induce transfer of color: "color inheritance": when applied at the level of amino-acids this leads to a successful model of protein folding. Reconnection makes possible breaking of flux tube connection for both the ordinary magnetic flux tubes and wormhole magnetic flux tubes.

4. How magnetic flux tubes are realized? The interpretation of flux tubes as correlates of directed attention at molecular level leads to concrete picture. Hydrogen bonds are by their asymmetry natural correlates for a directed attention at molecular level. Also flux tubes between acceptors of hydrogen bonds must be allowed and acceptors can be seen as the subjects of directed attention and donors as objects. Examples of acceptors are aromatic rings of nucleotides, $O =$ atoms of phosphates, etc.. A connection with metabolism is obtained if it is assumed that various phosphates XMP, XDP, XTP, $X = A, T, G, C$ act as fundamental acceptors and plugs in the connection lines. The basic metabolic process $ATP \rightarrow ADP + P_i$ allows an interpretation as a reconnection splitting flux tube connection, and the basic function of phosphorylating enzymes would be to build flux tube connections as also of breathing and photosynthesis.

The model makes several testable predictions about DNA itself. In particular, matter-antimatter asymmetry and slightly broken isospin symmetry have counterparts at DNA level induced from the breaking of these symmetries for quarks and antiquarks associated with the flux tubes. DNA cell membrane system is not the only possible system that could perform tqc like activities and store memories in braidings: flux tubes could connect biomolecules and the braiding could provide an almost definition for what it is to be living. Even water memory might reduce to braidings. The model leads also to an improved understanding of other roles of the magnetic flux tubes containing dark matter. Phase transitions changing the value of Planck constant for the magnetic flux tubes could be key element of bio-catalysis and electromagnetic long distance communications in living matter. For instance, one ends up to what might be called code for protein folding and bio-catalysis.

5.2.4 The Notion of Wave-Genome and DNA as Topological Quantum Computer

Peter Gariaev and collaborators have reported several strange effects of laser light and also ordinary light on DNA. These findings include the rotation of polarization plane of laser light by DNA, phantom DNA effect, the transformation of laser light to radio-wave photons having biological effects, the coding of DNA sequences to the modulated polarization plane of laser light and the ability of this kind of light to induce gene expression in another organisms provided the modulated polarization pattern corresponds to an "address" characterizing the organism, and the formation of images of what is believed to be DNA sample itself and of the objects of environment by DNA sample in a cell irradiated by ordinary light in UV-IR range. In this article a TGD based model for these effects is discussed. A speculative picture proposing a connection between homeopathy, water memory, and phantom DNA effect is discussed and on basis of this connection a vision about how the tqc hardware represented by the genome is actively developed by subjecting it to evolutionary pressures represented by a virtual world representation of the physical environment. The speculation inspired by this vision is that genetic code as well as DNA-, RNA- and amino-acid sequences should have representation in terms of nuclear strings. The model for dark baryons indeed leads to an identification of these analogs and the basic numbers of genetic code including also the numbers of aminoacids coded by a given number of codons are predicted correctly. Hence

it seems that genetic code is universal rather than being an accidental outcome of the biological evolution.

5.2.5 Evolution in Many-Sheeted Space-Time

The topics of the chapter has been restricted to those, which seem to represent the most well-established ideas. There are many other, more speculative, ideas such as the strong form of the hypothesis that plasmoid like life forms molecular life forms has evolved in "Mother Gaia's womb", maybe even in the hot environment defined by the boundary of mantle and core.

1. Basic facts about and TGD based model for pre-biotic evolution are discussed.

2. A model for the ATP-ADP process based on DNA as topological quantum computer vision, the identification of universal metabolic energy quanta in terms of zero point kinetic energies, and the notion of remote metabolism is discussed.

3. A model for the evolution of the recent genetic code (3-codons) as a fusion of codes for which codons are nucleotides (1-codons) and di-nucleotides (2-codons) is discussed. The symmetries of the genetic code, the observation that tRNA can be seen as a fusion of two hairpin like DNA molecules, and the finding that the first nucleotides of 3-codon code for the reaction path leading from a precursors of the aminoacid to aminoacids for hydrophobic/hydrohilic dichotomy, serve as motivations of the model. 1- and 2-codes corresponding to the two forms of RNA (the exotic $2' - 5'$ RNA and the usual $3' - 5'$ RNA) would have prevailed in RNA world. Aminoacids would have served as catalysts for the copying of RNA on one hand, and RNA molecules would have catalyzed the formation of aminoacids from their precursors on one hand, meaning the presence of a positive feedback loop. In the transition to DNA-aminoacid era RNA began to be translated to aminoacid sequences.

4. Cambrian explosion represents a rather mysterious period in biology: new highly developed phylas emerged out of nowhere. A second strange finding is that continents would fit together to form single super-continent covering entire Earth's surface at time of Cambrian explosion if the radius of Earth would have been one half of its recent value. This finding has inspired Expanding Earth theories but it has not been possible to identify the mechanism causing the expansion. The success of the standard tectonic plate theory requires that possible expansion must have occurred in relatively short geological time scale. The hierarchy of Planck constants implies that cosmic expansion has occurred in quantum leaps increasing the value of $\hbar$ and thus of quantum scales by factors which tend to be powers of 2. Cosmic expansion would have occurred as jerks even in the case of planets. In the proposed model Cambrian explosion would have accompanied the expansion of the Earth's radius by a factor of 2: during this period an outburst of highly developed life forms from underground seas to the surface of Earth would have taken place.

5. The last section of the chapter compares TGD based view about the evolution of genetic code to the views of McFadden. This section is a little bit out of date. For instance, the hypothesis that magnetic body of DNA could induce mutations purposefully is not discussed. This hypothesis is natural if one believes that magnetic flux tubes connecting bio-molecules play a key role in bio-catalysis. This idea is discussed in the chapter devoted to protein folding.

5.2.6 A Model for Protein Folding and Bio-catalysis

The model for the evolution of genetic code leads to the idea that the folding of proteins obeys a folding code inherited from the genetic code. After some trials one ends up with a general conceptualization of the situation with the identification of wormhole magnetic flux tubes as correlates of

attention at molecular level so that a direct connection with TGD inspired theory of consciousness emerges at quantitative level. This allows a far reaching generalization of the DNA as topological quantum computer paradigm and makes it much more detailed. By their asymmetric character hydrogen bonds are excellent candidates for magnetic flux tubes serving as correlates of attention at molecular level.

The constant part of free amino-acid containing $O-H$, $O=$, and NH_2 would correspond to the codon XYZ in the sense that the flux tubes would carry the "color" representing the four nucleotides in terms of quark pairs. Color inheritance by flux tube reconnection makes this possible. For the amino-adics inside protein $O=$ and $N-H$ would correspond to YZ. Also flux tubes connecting the acceptor atoms of hydrogen bonds are required by the model of DNA as topological quantum computer. The long flux tubes between $O=$ atoms and their length reduction in a phase transition reducing Planck constant could be essential in protein-ligand interaction.

The model predicts a code for protein folding: depending on whether also $=O-O=$ flux tubes are allowed or not, $Y=Z$ or $Y=Z_c$ condition is satisfied by the amino-acids having $N-H--O=$ hydrogen bond. For $=O-O=$ bonds $Y-Y_c$ pairing holds true. If one identifies hydrogen bond with flux tube ($Y(n)=Z(n+k)$) the model works badly for both options. If one assumes only that the presence of a flux tube connecting amino-acids in either direction ($Y(n)=Z(n+k)$ or $Z(n)=Y(n+k)$) is a prerequisite for the formation of hydrogen bond, the model works. $Y=Z_c$ option predicts the average length of alpha bonds correctly. $Y=Z$ rule is however favored by the study of alpha helices for four enzymes: the possible average length of alpha helix is considerably longer than the average length of alpha helix if gene is the unique gene allowing to satisfy $Y=Z$ rule. The explicit study of alpha helices for four enzymes demonstrates that the failure to satisfy the condition for the existence of hydrogen bond fails rarely and at most for two amino-acids (for 2 amino-acids in single case only). For beta sheets there ar no failures for $Y=Z$ option.

The information apparently lost in the many-to-one character of the codon-amino-acid correspondence would code for the folding of the protein and similar amino-acid sequences could give rise to different foldings. Also catalyst action would reduce to effective base pairing and one can speak about catalyst code. The DNA sequences associated with alpha helices and beta sheets are completely predictable unless one assumes a quantum counterpart of wobble base pairing meaning that $N-H$ flux tubes are before hydrogen bonding in quantum superpositions of braid colors associated with the third nucleotides Z of codons XYZ coding for amino-acid. Only the latter option works. The outcome is very simple quantitative model for folding and catalyst action based on minimization of energy and predicting as its solutions alpha helices and beta strands.

5.3   Part III: Mathematical models for genetic code and its evolution

The original hope was that genetic code could be understood in terms of number theoretic notion. This led to several mathematical models for the genetic code and its evolution. These models reproduced the code with a suitable choice of free parameters but failed to predict it whereas physics based approach led to the completely unexpected realization that genetic code could be understood at the level of elementary particle physics as something completely universal with chemical realization being only one particular representations of the code (see the chapter "The Notion of Wave-Genome and DNA as Topological Quantum Computer"). Also the chemical evolution could be understood on basis of physics based arguments. Hence this part might be argued to be somewhat obsolete but since the physical picture does not explicitly exclude number theoretic explanations I have decided to keep it.

5.3.1   Could Genetic Code Be Understood Number Theoretically?

The number of DNA triplets is 64. This inspires the idea that DNA sequence could be interpreted as an expansion of an integer using 64 as the base. Hence given DNA triplet would represent some

integer in {0,1....,63} (sequences of I Ching symbols give a beautiful realization of these sequences).

The observation which puts bells ringing is that the number of primes smaller than 64 is 18. Together with 0, and 1 this makes 20: the number of aminoacids!

1. Questions

The finding just described stimulates a whole series of questions.

Do aminoacids correspond to integers in the set $S = \{primes < 64\} \cup \{0, 1\}$. Does aminoacid sequence have an interpretation as a representation as a sequence of integers consisting of 0, 1 and products of primes $p = 2, ..., 61$? Does the aminoacid representing 0 have an interpretation as kind of period separating from each other structural units analogous to genes representing integers in the sequence so that we would quite literally consists of sequences of integers? Do 0 and 1 have some special biological properties, say the property of being biologically inert both at the level of DNA and aminoacids?

Does genetic code mediate a map from integers 0,...,63 to set S such that 0 and 1 are mapped to 0 and 1? If so then three integers $2 \leq n \leq 63$ must correspond to stopping sign codons rather than primes. What stopping sign codon property means at the level of integers? How the map from integers 2,...,61 to the primes $p = 2, ..., 61$ is determined?

2. The chain of arguments leading to a number theoretical model for the genetic code

The following chain of arguments induced to large part by concrete numerical experimentation leads to a model providing a partial answer to many of these questions.

1. The partitions of any positive integer n can be interpreted in terms of number theoretical many boson states. The partitions for which a given integer appears at most once have interpretation in terms of fermion states. These states could be identified as bosonic and fermionic states of Super Virasoro representation with given conformal weight n.

2. The generalization of Shannon entropy by replacing logarithms of probabilities with the logarithms of p-adic norms of probabilities allows to have systems with negative entropy and thus positive negentropy. The natural requirement is that n corresponds to such prime $p \leq 61$ that the negentropy assigned to n is maximal in some number theoretic thermodynamics. The resulting correspondence $n \rightarrow p(n)$ would naturally determine the genetic code.

3. One can assign to the bosonic and fermionic partitions a number theoretic thermodynamics defined by a Hamiltonian. Purely bosonic and fermionic thermodynamics are defined by corresponding partition functions Z_B and Z_F whereas supersymmetric option is defined by the product $Z_B \times Z_F$.

4. The simplest option is that Hamiltonian depends only on the number r of the integers in the partition. The dynamics would be in a well defined sense local and would not depend on the sizes of summands at all. The thermodynamical states would be degenerate with degeneracy factors given by total numbers $d_I(n, r)$ of partitions of type $I = B, F$. The invariants known as rank and crank define alternative candidates for basic building blocks of Hamiltonian.

5. Ordinary exponential thermodynamics based on, say $e^{-H/T} = q_0^{r-1}$, q_0 a rational number, produces typically unrealistic genetic codes for which most integers are mapped to small primes $p \leq 11$ and many primes are not coded at all. The idea that realistic code could result at some critical temperature fails also.

6. Quantum criticality and fractality of TGD Universe inspire the idea that the criticality is an inherent property of Hamiltonian rather than only thermodynamical state. Hence Hamiltonian can depend only weakly on the character of the partition so that all partitions contribute with almost equal weights to the partition function.

Fractality is achieved if Boltzmann factors are given by $e^{-H/T} = (r + r_0)^{n_0}$ so that $H(r) = log(r + r_0)$ serves as Hamiltonian and n_0 corresponds to the inverse temperature. The super-symmetric variant of this Hamiltonian yields the most realistic candidates for the genetic code and one might hope that a number theoretically small perturbation not changing the divisors $p \leq 61$ of partition function but affecting the probabilities could give correct degeneracies. Numerical experimentation suggests however that this might not be the case and that simple analytic form of Hamiltonian is too much to hope for.

Numerical experimentation suggests however that this might not be the case and that simple analytic form of Hamiltonian is too much to hope for. A simple argument however shows that $e^{-H/T} = f(r)$ could be in quantum critical case be deduced from the genetic code by fixing the 62 values of $f(r)$ so that the desired 62 correspondences $n \to p(n)$ result. The idea about almost universality of the genetic code would be replaced with the idea that quantum criticality allows to engineer a genetic code maximizing the total negentropy associated with DNA triplet-aminoacid pair.

A natural guess is that the map of codons to integers is given as a small deformation of the map induced by the map of DNA codons to integers induced by the identification of nucleotides with 4-digits 0,1,2, 3 (this identification depends on whether first, second, or third nucleotide is in question). This map predicts approximate $p(n) = p(n+1)$ symmetry having also a number theoretical justification. One can deduce codon-integer and aminoacid-prime correspondences and at (at least) two Boltzmann weight distributions $f(n)$ consistent with the genetic code and Negentropy Maximization Principle constrained by the degeneracies of the genetic code.

5.3.2 Unification of Four Approaches to the Genetic Code

A proposal unifying four approaches to genetic code is discussed.

The first approach is introduced by Pitkänen and is geometric: genetic code is interpreted as an imbedding of the aminoacid space to DNA space possessing a fiber bundle like structure with DNAs coding for a given aminoacid forming a discrete fiber with a varying number of points. Also Khrennikov has proposed an analogous approach based on the identification of DNAs coding for a given aminoacid as an orbit a discrete flow defined by iteration of a map of DNA space to itself.

Second approach starts from the 5-adic approach of Dragovich and Dragovich. Codons are labelled by 5-adic integers n which have no non-vanishing 5-digits so that the n is in the range $[31, 124]$. The number of primes in the range $[31, 124]$ is 20. This suggests the labelling of aminoacids by these primes. This inspires an additional condition on the geometric code: if possible, one of the integers n projected to p equals to $p(n)$. This condition fails only for the primes 53,79,101,103 for which some of 5-digits vanishing in 5-ary expansion.

The third approach is based on the generalization of the basic idea of the so called divisor code proposed by Khrennikov and Nilsson. The requirement is that the number of factors for integer n labelling one of DNAs, call it n_d coding for a given aminoacid is the total number of codons coding for the aminoacid, its degeneracy. Therefore a given aminoacid labelled by prime p with no non-vanishing 5-digits is coded by DNAs labelled by p itself and by n_d. A group theoretic and physical interpretation for the origin of the divisor code is proposed.

The fourth approach is a modification of the earlier 4-adic number theoretic thermodynamics approach of Pitkänen.

1. 5-adic thermodynamics involving a maximization of number theoretic negentropy $N_p(n) = -S_p(n) > 0(!)$ as a function of p-adic prime p labelling aminoacids assigns a unique prime to the codon. If no prime in the range divides S_p, the codon is identified as a stopping codon.

2. The number theoretic thermodynamics is assigned with the partitions P of the integer $n_{2)}$ determined by the first two letters of the codon (16 integers belonging to the range $[6, 24]$).

The integer valued number theoretic Hamiltonian $h(P) \in Z_{25}$ appearing in the Boltzmann weight $5^{h(P)/T_5}$ is assumed to depend on the number r of summands for the partition only. $h(r)$ is assumed to be tailored by evolution so that it reproduces the code.

3. The effect of the third nucleotide is described in terms of 5-adic temperature $T_5 = 1/n$, $n \in [0, 24]$: the variation of T_5 explains the existence of variants of genetic code and its temporal variation the observed context sensitivity of the codon-aminoacid correspondence for some variants of the code.

A numerical calculation scanning over $N \sim 10^{30}$ candidates for $h(r)$ allows only 11 Hamiltonians and with single additional symmetry inspired condition there are 2 solutions which differ only for 5 largest values of r. Due to the limited computational resources available only 24 percent of the available candidates have been scanned and the naive expectation is that the total number of Hamiltonians is about about 45 unless one poses additional conditions.

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