Quantum Control and Coordination in Bio-Systems: part I

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Abstract

The basic dynamical aspects of the biological system relate to coordination and control. Coordination is involved with almost automatic and predictable activities involving no volition whereas control involves volition and non-predictability. A basic examples of coordination and control are EEG and nerve pulse respectively. Various motor activities are good examples of a control involving macroscopic changes of the shape of the organ. The great challenge is to identify the quantum correlates of coordination and control.

The vision about living matter as consisting of a fractal hierarchy of MEs controlling a fractal hierarchy super-conducting magnetic flux tube structures in turn controlling ordinary matter at atomic space-time sheets via many-sheeted ionic flow equilibrium provides a very promising approach for modelling living matter. MEs interact with magnetic superconductors via magnetic induction by inducing supra-currents, by acting as Josephson junctions between magnetic flux tubes, and by inducing magnetic transitions.

The fact that TGD predicts infinite hierarchy of dark matters defining scaled down copies of color and electro-weak physics generalizes this picture dramatically and means that dark matter becomes the quintessential component of living systems. The predicted spectrum for the values of Planck constant conforms with quantum criticality since Kähler function does not depend on $\hbar$ and long range fluctuations at quantum criticality can be also interpreted as fluctuations in the value of $\hbar$ appearing only in the construction of quantum states and making possible macroscopic quantum coherence.

TGD suggests strongly that the formation of join the along boundaries bonds between the space-time sheets possibly representing different levels of the self hierarchy could be the basic mechanism of control and coordination. The interpretation as a prerequisite for bio-feedback, understood in very general sense, is very suggestive. The presence of join along boundaries bonds makes possible transfer of various charge particles between space-time sheets in question and the resulting system is very similar to two weakly coupled super conductors connected by Josephson junctions. This suggests that that super currents and Josephson currents between the space-time sheets are crucial for the coordination, which could be identified as deterministic quantum time development without quantum jumps.

Any harmonic perturbation with some magnetic transition frequency can induce magnetic quantum transitions and even magnetic quantum phase transitions. An attractive identification for this process is as basic tool of quantum control tool so that the resonance frequency appears as control parameter 'waking up' subself at its critical value. Critical frequencies correspond to the magnetic and Z^0 magnetic cyclotron frequencies in the model of super conductor relying on the presence of weak magnetic or Z^0 magnetic field (magnetic field guarantees effective one-dimensionality of the super conductor and implies finite gap energy in TGD framework). Cyclotron frequency hypothesis has had rather dramatic success and leads to a rather detailed picture about brain as a macroscopic quantum system.

This general picture is applied at various levels. A general model for weakly coupled super conductors is constructed and simple models for various control tools like comparison circuits, biological clocks and alarm clocks, feature detectors and novelty detectors are sketched. This model of quantum control is applied in some particular cases.

1 Introduction

The purpose of this and next chapter is to discuss a model of quantum control and coordination at general level and consider also some examples. Before dwelling down to the details, it is useful to briefly describe the basic philosophy in its present form.

1.1 Quantum criticality as a prerequisite for quantum control

Hierarchies involve masters and slaves. Master-slave hierarchy, defined in the spirit of Haken's theory of self-organization, is indeed a natural dynamical correlate of the self hierarchy. Quantum

control is possible only if the system is initial value sensitive, that is critical. TGD universe is indeed quantum critical: this also predicts the existence of macroscopic quantum phases in all length scales. Quantum criticality implies initial value sensitivity. There is very beautiful connection with information theoretic aspects: quantum critical universe is in a well defined sense the most intelligent and interesting universe that can exist in TGD framework. Quantum criticality fixes the value of the Kähler coupling strength as a parameter analogous to critical temperature and makes TGD a unique theory (as a matter fact, entire hierarchy of values corresponding to p-adic length scale hierarchy appears). $1/f$ noise, which seems to be universal phenomenon popping up in all kinds of contexts, provides direct evidence for quantum criticality. The standard explanation as self-organized criticality is subject to severe criticism since criticality by the definition is something unstable. Situation changes if the fundamental constant of Nature is analogous to critical temperature: there exists simply no perturbations external to the entire universe changing the value of a fundamental constant.

Spin glass analogy could be regarded as one aspect of quantum criticality and states the TGD universe can be regarded as quantum spin glass. Quantum spin glass is phenomenologically characterized by its fractal energy landscape containing valleys inside valleys inside valleys giving rise to extremely complicated system. Quantum self-organization can be described as motion in this kind of energy landscape. p-Adicity can be regarded as one aspect of the quantum spin glassiness. Biosystem as a self-organizing quantum critical spin glass together with the notion of many-sheeted space-time provides rather restrictive general guide line for attempts to construct a general theory of bio-control and -coordination.

1.2 p-Adic evolution

p-Adic unitarity implies automatically evolution as a gradual increase of the p-adic prime of the universe. The infinite size of the universe forces to introduce the notion of infinite primes and corresponding p-adic topologies. Infinite primes have decomposition into finite primes labelling space-time sheets possessing p-adic topology. The notion of infinite prime allows to understand the evolution as two kinds of processes. First process is continuous and corresponds to a gradual increase of the finite p-adic prime associated with the existing physical system. Second process is discontinuous and involves the emergence of entirely new p-adic space-time sheets. The gradual increase of the cell size during evolution and the sudden emergence of multicellular structures provide examples of these two aspects of the evolution. The increase of the finite prime corresponds to a gradual refinement of the corresponding p-adic topology in the sense that the notion of nearness as it is realized at the level of conscious experience, becomes more and more refined. Also the maximum information content of conscious experiences increases with p-adic prime. Thus a measure for the complexity of a conscious system is in question. Identification of p-adic physics as physics of cognitive representations adds considerable concreteness to this vision and one ends up with rather concrete ideas about how thought is transformed to actions and sensory input is transformed to thought.

1.3 Self-hierarchy, quantum self-organization, and dissipation as a Darwinian selector

The breakthrough idea in TGD inspired theory of consciousness was the notion of self defined as a subsystem able to remain p-adically unentangled during the unitary quantum "time evolutions" U associated with quantum jumps $\Psi_i \to U\Psi_i \to \Psi_f$. The notion of self leads to the notion of self hierarchy and the interpretation of quantum self-organization as evolution of selves.

A system possessing self (possibly having sub-selves) performs quantum jumps and dissipates. This leads to quantum self-organization leading to asymptotic patterns selected by dissipation,

which thus acts as a Darwinian selector of both memes and genes. Actually, there is no deep difference between genes and memes (understood here rather metaphorically) since selves are always conscious systems and consciousness is present already at elementary particle level. In light of this, the notion of the self hierarchy should be of crucial importance for the understanding of living systems and the purpose of this chapter is to demonstrate this and also to propose a general view about how biological self hierarchy is realized dynamically.

One of the important consequences of the quantum self-organization is that it provides justification for the use of cybernetic notions in the description of bio-systems. Many neuroscientists (and even physicists!) who claim that it is possible to understand brain in terms of classical notions fail to realize that the notions used are very far from classical. For instance, Hodkin-Huxley equations for nerve pulse involve in an absolutely essential manner dissipation. It is the very presence of self which makes dissipation possible! Actually any description involving kinetic equations and irreversibility instead of classical field equations implicitly assumes that system is part of self! In particular, the notions of feedback, neural circuits, excitation, inhibition, signalling,... are all notions, which are not possible in the context of classical physics. The basic signature of self is that it seems the world look like classical in the eyes of neuroscientist!

1.4 Macro-temporal quantum coherence and spin glass degeneracy

Macroscopic and macro-temporal quantum coherence is an essential element of quantum consciousness theories: for instance, quantum coherence is necessary prerequisite for quantum biocomputation. The basic objection against these theories is that the de-coherence time, which tells in which time scale Schrödinger equation applies, is quite too short to allow macroscopic coherence in the required time scales which could be even of order .1 seconds [34].

These arguments are however based on a theory, which contains an inherent logical contradiction (nondeterminism of quantum jump contra determinism of Schrödinger equation) and rely on standard physics. In TGD the mentioned contradiction disappears, and standard physics is replaced with a physics in many-sheeted space-time. In particular, zero modes and quantum spin glass degeneracy emerge as completely new elements absent from quantum quantum field theories, and it turns out that these elements allow to understand how macro-temporal quantum coherence is generated. A close relation with the ideas of Penrose and Hameroff results because spin glass degeneracy is due to the presence of a large number of space-time sheets differing only by their classical gravitational energy. Spin glass degeneracy is mathematically identical with a broken $U(1)$ gauge symmetry since CP_2 canonical transformations leaving induced Kähler form invariant and acting as approximate symmetries act like $U(1)$ gauge transformations.

In TGD framework each quantum jump can be interpreted as quantum computation performed by entire universe. Unitary process $\Psi_i \to U\Psi_i$, where Ψ_i is a prepared maximally unentangled state, corresponds to the quantum computation. Then follows state function reduction and state preparation involving a sequence of self measurements and given rise to a new maximally unentangled state Ψ_f.

The problem is that simplest estimate for the increment of the psychological time in single quantum jump is about 10^{-39} seconds from the idea that single quantum jump is a kind of elementary particle of consciousness and thus corresponds to CP_2 time. This would mean that 10^{39} quantum computations occur during single second and conscious experience is average over these quantum computations and the result of the computation would be averaged out completely. This would look like another manner to say that quantum computation is not possible.

That Nature would not allow quantum computation in time scales much above CP_2 time scale looks strange, and conflicts even the standard physics prediction. Indeed, the fractality of TGD Universe suggests also the fractality of consciousness in the sense that sequences of quantum jumps ('elementary particles' of consciousness) should somehow bind to form effectively single

quantum jump just like bound states of elementary particles give rise to atoms, molecules, etc... behaving in many respects like elementary particle. This kind of situation indeed results if the quantum entanglement associated with the quantum computer is bound state entanglement stable against self measurements and if the quantum computer self is in a state of 'irreducible selfness' and therefore stable against self measurement. Paradoxically, in mystics this corresponds to the state of oneness without any mental images: the total emptiness of mind would be crucial for quantum computation which is the most effective manner to perform information processing! In this case quantum jumping could preserve bound state for quite a long time. The halting would be caused by an external perturbation destroying the bound state. The properties of the bound state plus interaction with environment would allow to estimate the typical duration of the quantum computation. This time would take the role of coherence time. This would suggest connection with the standard approach to quantum computation.

Irreducible self-ness is not enough for quantum computation. Macro-temporal quantum coherence in the sense that zero modes for the three-surface cease to be zero modes under some conditions, is also necessary for quantum computation. The reason is that localization in the zero modes corresponds to state function reduction spoiling the quantum coherence.

There is indeed a mechanisms transmuting zero modes to quantum fluctuating degrees of freedom. The formation of join along boundaries bonds between 3-D space sheets implies that only the 'center of mass' zero modes remain whereas relative zero modes become quantum fluctuating degrees of freedom. The increase of the lifetime of the bound state is simply due to the fact that the 'phase space volume' associated with the bound states is very large, that is the number of almost degenerate bound states is very large due to the spin glass degeneracy of the join along boundaries bonds. In unbound state these bonds are not present.

This option looks realistic and is very natural in the case of tubulins and water molecules which indeed form join along boundaries condensates. The formation of join along boundaries bonds is indeed the basic mechanism for the formation of macroscopic quantum states and the correlate for bound state quantum entanglement. This would explain why water is so important for life.

Whether one can one approximate quantum jump sequence as unitary Hamiltonian time evolution in case of a bound state is an open question. Fractality of consciousness would suggest that one can in case of quantum coherence effectively treat long quantum jump sequence as a single quantum jump (just like one can treat molecules as point like particles in a reasonable approximation) so that Hamiltonian description might make sense. Hamiltonian time evolution would more or less correspond to a unitary operator resulting as a product of the actions of the unitary operators U associated with the quantum jumps of the sequence. Discretized time development would emerge automatically in this framework. Schrödinger equation at infinitesimal level would not make sense but this is of course not a practical problem.

The fact that oxidative metabolism is anomalously low during a neuronal synchrony supports the view that neuronal synchrony might give rise to bound-state entangled multineuron states in 'state of oneness'(the liberated binding energy would be usable energy). The quantum computations performed by the neuronal groups might last the typical duration of 'feature', which is about .1 seconds, typical time scale of alpha rhythm. Also breaking of second law of thermodynamics is predicted in time scale of the bound state. p-Adic length scale hypothesis actually suggests an entire hierarchy of breakings of second law occurring below p-adic time scale.

1.5 TGD based view about dark matter

TGD suggests an explanation of dark matter as a macroscopically quantum coherent phase residing at larger space-time sheets [J6].

1. TGD suggests that $\hbar$ is dynamical and possesses a spectrum expressible in terms of generalized Beraha numbers $B_r = 4cos^2(\pi/r)$, where $r > 3$ is a rational number [C6, J6]. Just

above $r = 3$ arbitrarily large values of $\hbar$ and thus also macroscopic quantum phases are possible. The criterion for transition to large $\hbar$ phase is the failure of perturbative expansion so that Mother Nature takes care of the problems of theoretician. A good guess is that the criticality condition reads as $Q_1 Q_2 \alpha \simeq 1$ where Q_i are gauge charges and α gauge coupling strength. This leads to universal properties of the large $\hbar$ phase. For instance, $\hbar$ is scaled in the transition to dark phase by a harmonic or subharmonic of parameter $1/v_0 \simeq 2^{11}$ which is essentially the ratio of CP_2 length scale and Planck length [D6, J6]. The criticality condition can be applied also to dark matter itself and entire hierarchy of dark matters is predicted corresponding to the spectrum of values of $\hbar$.

2. The particles of dark matter can also carry phase carry complex conformal weights but the net conformal weights for blocks of this kind of dark matter would be real. This implies macroscopic quantum coherence.

3. An infinite hierarchy of dark matters is predicted [F6]. The basic hierarchy corresponds to the values of $\hbar$ coming as $\lambda^m \hbar(1,m)$, $\lambda = v_0/n$, $v_0 \simeq 2^{11}$. $\hbar(1,m)$ corresponds to the values of $\hbar$ labelled by Beraha numbers B_m. Second hierarchy corresponds to particles labelled by selected integers characterizing the p-adic length scales of particles with which the particle interacts. Direct interactions occur only between the particles characterized by integers having common p-adic prime factors characterizing the p-adic length scales of bosons exchanged in the interaction. The algebraic extensions of p-adic numbers define an additional hierarchy. Also the notion of darkness must be refined by attributes partial and relative.

4. From the point of view of nuclear physics application of this hypothesis is to QCD. The prediction is that the electromagnetic Compton sizes of dark quarks are scaled from $L(107)$ to about $2^{11}L(107) = L(129) = 2L(127)$, which is larger than the p-adic electromagnetic size of electron! The classical scattering cross sections are not changed but changes the geometric sizes of dark quarks, hadrons, and nuclei. The original hypothesis that ordinary valence quarks are dark whereas sea quarks correspond to ordinary value of $\hbar$ is taken as a starting point. In accordance with the earlier model, nucleons in atomic nuclei are assumed to be accompanied by color bonds connecting exotic quark and anti-quark characterized p-adic length scale $L(127)$ with ordinary value of $\hbar$ and having thus scaled down mass of order MeV. The strong binding would be due the color bonds having exotic quark and anti-quark at their ends.

5. Quantum classical correspondence suggests that classical long ranged electro-weak gauge fields serve as classical space-time correlates for dark electro-weak gauge bosons, which are massless below the appropriate weak length scale L_w. This hypothesis could explain the special properties of bio-matter, in particular the chiral selection as resulting from the coupling to dark Z^0 quanta. Long range weak forces present in TGD counterpart of Higgs=0 phase should allow to understand the differences between biochemistry and the chemistry of dead matter.

6. For ordinary condensed matter quarks and leptons Z^0 charge are screened in electro-weak length scale whereas in dark matter $k = 89$ electro-weak space-time sheet have suffered a phase transition to a p-adic topology with a larger value of k. Gaussian Mersennes, in particular those associated with $k = 113, 151, 157, 163, 167$ are excellent candidates in this respect. The particles of this exotic phase of matter would have complex conformal weights closely related to the zeros of Riemann Zeta. The simplest possibility is that they correspond to a single non-trivial zero of Zeta and there is infinite hierarchy of particles of this kind.

In dark matter phase weak gauge fluxes could be feeded to say $k = k_Z = 169$ space-time sheet corresponding to neutrino Compton length and having size of cell. For this scenario to make sense it is essential that p-adic thermodynamics predicts for dark quarks and leptons essentially the same masses as for their ordinary counterparts [F3].

1.6 Topological field quantization

Topological field quantization assigns to various quantum concepts rather precise geometrical correlates. Absolute minimization of Kähler action implies that the space-time surface associated with given 3-surface satisfies generalized Bohr rules so that something generalizing Bohr model of atom to the level of classical fields results as an exact part of the quantum theory. Also virtual and real particles of quantum field theories have classical correlates. In particular, virtual particles corresponds to cognitive space-time sheets representing geometric correlates for selves. Furthermore, topological field quanta are characterized by vacuum quantum numbers very much analogous to ordinary quantum numbers and topological field quantum defines a unique selection of quantization axes for spin and color quantum numbers.

The p-adic hierarchy of the space-time sheets indeed provides a geometrical and topological realization for the self hierarchy already discussed in detail in the previous chapter. The real power of the notion of topological field quantization came apparent, when it became clear that the topological field quanta associated with ELF em fields with frequencies in EEG frequency range must be correlates of our sub-selves (mental images). This means a radical reconsideration of the basic assumptions of neuroscience. What makes this radical rethinking unavoidable is that one can indeed understand the important frequencies of the EEG and one ends up with a precise quantitative model for cognition and sensory experience. In particular, a general quantum model of coordination and control emerges.

The most important topological field quanta are magnetic flux tubes which are identified as carries of super-conducting ionic BE condensates. They form a fractal hierarchy. Massless extremals (MEs) are second extremely important class of topological field quanta and are for radiation fields what Bohr orbits are for the atom. There is also a close connection with the geometric optics. MEs are ideal for communication purposes both at classical and quantum level. The light like boundaries of MEs are carriers of super-conformal and super-canonical representations having gigantic almost-degeneracies broken only by the non-commutativity of Poincare transformations and super-canonical transformations. The boundaries of MEs are quantum holograms in the sense of quantum gravity. The light like vacuum currents associated with MEs in turn define dynamical classical holograms and there are good reasons to expect that MEs make possible quantum teleportation of electromagnetic states. Super-canonical states are genuinely quantum gravitational states defined in the space of 3-surfaces whereas magnetic states (actually all states predicted by quantum field theories) can be effectively reduced to states associated with single 3-surface. This means that MEs are definitely above the super-conducting magnetic flux tubes in the hierarchy of consciousness and should control what happens at magnetic flux tubes. Perhaps our consciousness is associated with MEs whereas 'body consciousness' would be associated with magnetic super-conductors.

The hypothesis that the topological field quanta associated with a material system provide a representation for the system's quantum properties provides a strong interpretational tool. For instance, electromagnetic transition frequencies should correspond to MEs having lengths equal to the transition wavelengths and binding energies should correspond to negative energy MEs with length determined by the binding energy. This topological self reference leads to the notion of field body. Any system has a field body which serves as a kind of manual providing a symbolic representation about the system: this representation is not possible in Maxwell's theory. In the case of DNA the field body provides a higher level representation of the genetic information. In the case of human body the field body provides among other things a representation for the state

of brain: EEG MEs have lengths measured using Earth size as unit but also ULF MEs necessary for the realization of the long term memory and having lengths measured in light years are present. This picture inspires also the hypothesis that sensory representations are realized at the magnetic sensory canvas provided by the flux tubes or shell like topological field quanta of Earth's magnetic field. The magnetic mirrors formed by the magnetic flux tubes emanating from the body and parallel MEs serve as projectors to the magnetic sensory canvas.

1.7 Important empirical inputs and overall view

The development of the ideas about quantum control has occurred in jumpwise manner with jumps being induced by some crucial empirical inputs. My own meager knowledge about biology has certainly been one important factor hindering systematic development of the ideas.

Ironically, the needed empirical data providing direct evidence for the importance of the ionic super-conductors has existed already at seventeens [51, 52] and I encountered them almost accidentally (at least it looks so)! Thanks for this are due to Gene Johnson from whom I learned a lot about brain as seen by neuroscientist. These data convincingly demonstrate that cyclotron resonance frequencies of various ions in Earth's magnetic field are very special. Electromagnetic fields at these frequencies or modulated by these frequencies have unexpected and poorly understood effects on living matter and brain. Even more, important EEG frequencies correspond to multiples of the cyclotron frequencies of the basic ions involved with the nerve pulse generation. Most importantly, the data provide the long sought-for direct evidence for bio-systems as macroscopic quantum systems! This empirical input made it possible integrate the bundle of ideas about bio-systems as macroscopic quantum systems to a general model of how coordination and control are realized in living systems.

A second decisive input where the observation that the frequencies of the BE condensed photons associated with the massless extremals (MEs) correspond in EEG frequency range to important EEG resonance frequencies if one assumes that p-adic length scales define preferred lengths for MEs [M4]. Together with the inspiration coming from the vision of Peter Marcer about bio-systems as quantum holograms [46], and the realization that the light like boundaries of MEs can be regarded as seats for so called super-canonical representations providing huge information resources, this observation led to the realization that the fractal hierarchy of MEs must represent the highest control level in bio-system.

The third crucially important empirical input were the empirical findings challenging the notions of ionic channels and pumps [47]. The explanation of these data led to a rather concrete model for homeostasis as a many-sheeted ionic flow equilibrium. This picture allows to understand how extremely low densities of super-conducting ions at super-conducting magnetic flux tube structures can control much higher ionic densities at atomic, non-super-conducting space-time sheets: the basic formula relates the ratio of densities of ions at atomic and super-conducting space-time sheet to the inverse of the corresponding flow velocities.

Coherent electric fields at atomic space-time sheets are required in order to have non-vanishing ohmic currents and this explains why bio-matter is liquid crystal having as a consequence also the electret property. In this picture one can understand also the role of DC current circuitry discovered already by Becker [50]. Also the ideas of Mae Wan-Ho about control current circuitry formed by collagen network fits nicely with vision about many-sheeted ionic flow circuitry. A further support for this vision is provided by the empirical evidence for water memory and various effects involved with it [42, 43, 44, 45]. Many-sheeted ionic flow equilibrium suggests an elegant mechanism of homeopathy: the extremely low densities of homeopathic remedies are at the controlling super-conducting space-time sheets where the control is. Thus homeopathy can be seen as a high precision medicine minimizing the amount of the remedy needed [J1, J2, J3, K5] rather than some kind of magic treatment.

1.8 Quantum coordination and control and the hierarchy of MEs, magnetic super conductors, electrets and bio-matter

Basic dynamical aspects of a biological system relate to coordination and control. Coordination is involved with almost automatic and predictable activities involving no volition whereas control involves volition and non-predictability. Basic examples are coordination and control are EEG and nerve pulse respectively. Various motor activities are good examples of control involving macroscopic changes of the shape of the organ.

The basic question, to be addressed in this chapter, concerns about the dynamical realization of the coordination and control. The TGD inspired vision about bio-system is as a symbiosis of the fractal hierarchies of MEs and magnetic super-conductors, with bio-matter. MEs represent the highest hierarchy level controlling magnetic super-conductors which in turn control and coordinate the behavior of the non-super-conducting matter at atom space-time sheets by ionic flow equilibrium. Atoms of condensed matter can possess anomalous Z^0 charge vacuum screened in atomic length scale [F8, F9]. Also Z^0 super-conductivity is possible: thus the control of also neutral atomic and molecular densities is possible. The control operations presumably involve momentary loss of flow equilibrium: the simplest control mechanism is 'let it go for a moment'.

The great challenge is to identify the basic mechanisms of quantum control and coordination.

1. TGD suggests strongly that the formation of join the along boundaries bonds between the space-time sheets possibly representing different levels of the self hierarchy could be one of the basic mechanism of control and coordination. The interpretation as a prerequisite of bio-feedback, understood in very general sense, is very suggestive. The presence of the join along boundaries bonds makes possible transfer of various particles between space-time sheets in question (for instance, atomic and super-conducting space-time sheets).

2. Space-time sheets connected by join along boundaries bonds form a system very similar to two (weakly) coupled super conductors connected by Josephson junctions. This suggests that that Josephson currents between the space-time sheets are crucial for the coordination. The Josephson currents would act effectively as an interaction Hamiltonian representing harmonic perturbation coupling to each other single particle state basis localized in either super conductor and having overlap only in the Josephson junctions. If the frequency of the Josephson current acting as a harmonic perturbation of super conductors, equals to the energy difference for single particle states of either super conductor, the standard rules of quantum mechanics predict the possibility of quantum jumps between these states. When the frequency of the Josephson current is not equal to energy difference, quantum jumps do not occur at the limit of an infinitely long interaction time. This suggests that harmonic perturbations provide a general mechanism of quantum coordination and control: by tuning the frequency of the Josephson current quantum master can 'wake-up' the quantum slave. Large Josephson currents can induce failure of flow equilibrium and lead to non-equilibrium processes crucial for control.

3. Join along boundaries contacts can and must allow also the flow direct supra currents or Ohmic currents above critical velocity. SQUID type circuit is a good analog for the situation. A very natural interaction mechanism between MEs and super-conducting circuits is magnetic induction ($\Phi = LI$ modulo flux quantum), which induces supra-current guaranteeing the quantization of magnetic flux in the circuit. The em fields associated with MEs can also induce magnetic quantum transitions possibly amplified to quantum phase transitions. Of course, also other than magnetic quantum transitions might be amplified by the quantum coherence of the BE condensate. These transitions could very effectively modulate the chemical properties of, say enzymes. The super-conducting electrons at space-time sheets associated with the molecular space-time sheets could be in electronic flow equilibrium with

atomic space-time sheets and control the conformation of the molecule very effectively. MEs in turn could control the supra-currents by magnetic interaction and thus the conformations of molecules. Thus the super-conducting magnetic flux tubes are tailor-made for biochemical control.

4. There is also a feedback loop from the magnetic super-conductors to MEs since quantum phase transitions induce emission of photons which can Bose-Einstein condense to MEs carrying collinear BE condensates of photons (and also gravitons). For instance, endogenous NMR spectroscopy and its generalizations could be possible in this manner if magnetic flux tubes have varying thickness! This NMR might be basically responsible for chemical senses.

5. It took quite a long time to fully realize the obvious. Bio-systems are full of electrets and TGD indeed predicts the flux quanta of electric fields as basic solutions of field equations dual to the magnetic flux tubes. Also TGD counterparts of Tesla's scalar waves are predicted as special case of these solutions.

6. The newest and perhaps the most fundamental element of bio-control is time mirror mechanism. Many-sheeted space-time makes possible many-sheeted lasers since cold space-time sheets can contain Bose-Einstein condensates of ions and their Cooper pairs. If the system contains population inverted many-sheeted laser for which the increment of zero point kinetic energy corresponds to the energy of photons associated with negative energy MEs, the absorption of negative energy photons gives rise to a phase transition like dropping of particles to larger space-time sheet by the induced emission mechanism, and the control signal represented by negative energy MEs can be amplified if a critical number of particles drops to the larger space-time sheet. This control mechanism allows an instantaneous motor control in which intention is transformed to desired represented by negative energy MEs and generates in geometric past a reaction representing the desired response, say neuronal activity giving rise to motor action. This process probably involves entire hierarchy of magnetic selves realizing their intentions as desires communicated to lower level magnetic selves and the lowest level corresponds to the regions of brain responsible for liberating metabolic energy.

In this and next chapter my aim is to describe the general view about how quantum coordination and control in bio-systems is realized. In this chapter main emphasis is on super conductivity and many-sheeted ionic flow equilibrium. Next chapter is devoted to field aspect, to the time mirror mechanism as a means to transform intentions to actions, and to the role of classical Z^0 fields in living matter. Reader can find more details about various macroscopic quantum phases involved from subsequent chapters of the book. It must be emphasized that the picture is still evolving and I have not simply had time to integrate various elements in the big and complex picture to single coherent whole.

2 Bio-systems as macroscopic quantum systems

Bio-systems contain quantum sub-systems, which can have macroscopic size. For example, organic polymers, nerve cell, muscle fiber and brain could be systems of this kind. The formation of the larger quantum systems from smaller ones is achieved by the join along boundaries bond. At molecular level this corresponds to the formation of a chemical bond [32] so that macromolecules result. At cell level this means that the lipids and/or proteins of the layers of the cell membrane are joined together by chemical bonds. At the level of organ, say brain, a good candidate for the join along boundaries bond is gap junction [33] joining neighboring cells together. These gap junction connected structures are very general in bio-system. For instance, sensory organs are gap junction connected structures of neurons and also brain contains these structures.

2.1 # contacts as a macroscopic quantum system?

An excellent candidate for a macroscopic quantum system is provided by # contacts. # contacts must have small inertial mass, which by a dimensional argument must be of order $1/L(n)$, where $L(n)$ is the lower bound for the size of a typical 3-surface at a given condensation level. The presence of the energy gap, given by the rest mass of the # throat, suggests that they can form Bose Einstein condensates located on the boundaries of the 3-surface.

Charged # contacts are especially interesting in this respect. They couple extremely weakly to radiation fields, which explains why they have not been observed and also implies that the BE condensate of # contacts is thermally isolated from the ordinary matter. The coupling to the difference of the classical gauge potentials associated with the two space-time sheets connected by them can give rise to a relatively strong, purely classical interaction. Therefore charged # contacts behave very much like Cooper pairs and the concepts of Josephson current and Josephson junction generalize. # contacts are located near the boundaries of the smaller 3-surface and appear in all length scales. These properties make # contacts an ideal tool of bio-control at quantum level and it might well be that they appear in all the relevant scales associated with the bio-systems.

contacts couple to the difference of the gauge potentials serving as order parameters for the coherent photons topologically condensed on the two space-time sheets connected by # contact and this suggests that the coupling of # contacts to coherent light might serve as a important biological function. Indeed, this kind of coupling provides an explanation for the so called Comorosan effect involving an interaction between laser light and organic molecules, which is not understood in the standard physics context [48, 49].

The so called wormhole magnetic fields are two-sheeted structures with finite spatial size containing magnetic fields of same magnitude but opposite direction at the two space-time sheets involved. The magnetic fields are created by wormhole currents residing at the boundaries of the structure. Wormhole magnetic might also have a key role also in bio-systems in providing simplest possible almost vacuum space-time surface of finite spatial size serving as a concrete model for association sequence. For instance, axons and various other linear structures could correspond to the concentrations of ordinary matter around the flux tubes of magnetic or even wormhole magnetic fields. Wormhole magnetic fields provide cognitive representations and the simplest representation is direct mimicry. Thus mind like space-time sheets could carry classical fields of same intensity as material space-time sheets but having as their sources currents of wormhole contacts: this kind of mechanism could provide explanation for some exotic effects like homeopathy [J5].

2.2 Do micro-tubuli act as quantum antennae?

Micro-tubuli are believed to play key role in the information processing of the cell and there are lots of speculations about the possibility that micro-tubuli are mesoscopic quantum systems. In TGD context there is indeed a very general mechanism leading to the generation of the coherent photons and gravitons. The point is that the classical induced gauge fields need can give rise to non-vanishing vacuum currents generating coherent states of photons or gravitons. The many-sheeted nature of space-time suggests the presence of almost vacuum space-time sheets and the so called massless extremals studied in [J4] provide an excellent candidate for an almost vacuum space-time leading to the generation of coherent photons and gravitons. The simplest massless extremals are cylindrical structures and the vacuum gauge currents run along the cylinder with light velocity. Also the Einstein tensor is light like. The frequencies of the coherent photons come as multiples of π/L, where L is the length of the structure. These cylindrical structures clearly act as quantum antennae both sending and receiving coherent photons.

Micro-tubuli represent an important example of a linear bio-structure and an attractive possibility that they are accompanied by a space-time sheet, which is in a good approximation massless extremal having weak coupling to the ordinary space-time sheets containing the bio-matter and

thus providing a representation for some aspects of the exterior world in the properties of the vacuum current. Of course, also DNA and other linear structures could act as quantum antennae and quantum antenna mechanism might be completely generic and length scale independent mechanism in the bio-systems.

2.3 Classical Z^0 force, neutrinos and chirality selection

The arguments related to the smallness of the parity breaking effects in nuclear, atomic and molecular length scales led to the assumption that elementary particles feed their Z^0 gauge charges to the condensate levels having $L(k) \geq L(k_Z) \geq \xi \simeq 4 \times 10^{-6}$ m: this length scale corresponds to the cell length scale and also to the Compton length for neutrinos having mass of order one eV. The simplest assumption is that all Z^0 charge is fed at this level. Classical Z^0 force is screened by the neutrinos and a model for the destruction of the super fluidity by Z^0 magnetic vortices leads to the rough estimate $\epsilon_Z \in (10^{20} - 20^{22})$ for the parameter ϵ_Z describing screening ($1/\sqrt{\epsilon_Z}$ is the ratio of unscreened Z^0 charge density to the nuclear Z^0 charge density).

The appearance of the classical Z^0 force suggests an explanation for the chirality selection of the organic molecules taking place in vivo. Very roughly the idea is as follows: the axial part of Z^0 field couples to the spin of neutrinos. Parity breaking effects are small unless there is a net magnetization of neutrinos and this magnetization could be caused by the classical Z^0 magnetic fields inside the cell. These magnetic fields can be strong since they are caused by the moving nuclear Z^0 charge (neutrinos probably do not follow the motion of matter). The tritium beta decay anomaly [F8] provides direct evidence for the presence of classical Z^0 force in condensed matter systems. The magnetized regions in turn could have interpretation as "thinking regions" of space-time in accordance with the interpretation of fermionic state basis as Boolean algebra.

2.4 Are bio-systems super-conductors?

The interpretation of the state basis (2^N states) of the fermionic Fock space generated by N creation operators as a Boolean algebra of statements about N basic statements suggests that quantum jumps in the fermionic sector might have something to do with Boolean and quantitative aspects of consciousness. Quantification is here understood as an ability to associate to sensory experience an integer represented as a bit sequence such that bit is represented as the value of fermion number or as the direction of fermion spin. This conforms with the earlier speculations about the fundamental role of defects in type I neutrino super conductors if one identifies defects as "thinking" regions, where Fock basis is natural whereas in super-conducting phase basic particles are bosons. As suggested already earlier, one could also interpret the almost topological vacuum quantum numbers characterizing the magnetic flux associated with the defects as a biologically relevant information. Cell membranes and endoplasma membranes having local stripe like structure indeed resemble defects in type I super conductors. A tentative guess is that bio-systems can be both electronic and neutrino super conductors and that there exist magnetic and/or Z^0 magnetic fields in these regions leading to ordinary and/or Z^0 magnetization.

Atomic space-time sheets are not expected to be electronic super-conductors for obvious reasons but the space-time sheets with larger size contain very small charge densities and super conductivity at these space-time sheets might be possible. A mechanism leading to the presence of electrons at 'non-atomic' space-time sheets would be the 'dropping' of the atomic electrons to the larger space-time sheets so that "exotic atoms" are formed. 'Dropping' could take place via a temporary formation of join along boundaries bonds connecting the space-time sheets in question: in this case exotic phases are probably near the boundaries of the larger space-time sheet. If valence electrons are in question, this phenomenon leads to 'electronic alchemy'. The formation of the exotic atoms is necessarily accompanied by a destruction or a formation of charged # contacts or their flow

between space-time sheets joined together by join along boundaries bonds since the net charge of the atomic space-time sheet changes.

A possible mechanism leading to the formation of the Cooper pairs is analogous to the ordinary mechanism based on the phonon exchange. The Coulombic and magnetic interaction of electrons with the # contacts generating the excitations of the # contact BE condensate is analogous to the induction of phonon exchange by the electron-nucleus classical electromagnetic interaction and could give rise to an attractive force between electrons. Since the space-time sheets in question are almost empty, the Cooper pairs could be even thermally shielded. The large value of the gap energy could also make the super conductor in question stable.

Also ionic super conductivity relying on the dropping of ions to cellular space-time sheets is possible and supported by empirical findings. The first observations about the special effects of ELF em fields on brain at cyclotron frequencies of ions Na_+, Cl^-, K_+, Ca_{++} and electron in Earth's magnetic field to brain were made already at seventies [51, 52]. These experiments suggest strongly that these ions/their Cooper pairs are confined in the magnetic field of Earth and form bound states with macroscopic size of order cell size and extremely small binding energy corresponding to frequency of order 10 Hz. This is certainly not possible in the standard physics framework but can be understood as resulting from the dropping of ions and electrons from the atomic space-time sheet to the space-time sheet of the cell where the density of the matter is very low. There is very cold, dry and silent at the cellular space-time sheets and this makes possible macroscopic quantum phases formed by Cooper pairs of ions Na_+, Cl^-, K_+ and electron as well as well as Ca_{++} ions. Also other ions are possible but these ions are especially important for EEG.

Besides magnetic cyclotron frequencies Z^0 magnetic cyclotron frequencies and even wormhole cyclotron frequencies make sense: Z^0 currents for ions indeed induce automatically also ionic currents. One can quite well consider the possibility that neutral atoms and their Cooper pairs give rise to Z^0 super conductors, or equivalently, super fluids.

The effects related to water memory and claimed effects of homeopathy [45] suggest that not only ions but only molecules (such as proteins) could form BE condensates at the magnetic flux tubes: these effects are discussed in detail in [J1, J2, J3]. This would obviously open fantastic possibilities as far as quantum level bio-control is considered. A strong support for the notion of many-sheeted space-time and super-conductivity at non-atomic space-time sheets comes from the findings challenging the notions of ionic channels and pumps [47] (see [J1, J2, J3]).

In case of neutrinos, the interaction with the atomic nuclei via classical Z^0 magnetic fields induces phonon exchange mechanism essentially identical to the ordinary mechanism of super conductivity and the effective absence of Z^0 quanta makes the situation ideal for super conductivity. The breaking of neutrino super-conductivity could be caused in the cell membrane length scale by nuclear Z^0 magnetization leading to the generation of strong Z^0 magnetic fields: the same mechanism would also explain the chirality selection in living matter. According to quark model estimates, also proton has large anomalous Z^0 magnetic moment, so that ordinary magnetization could be accompanied by Z^0 magnetization.

2.5 Are all magnetic transition frequencies important for the understanding of conscious experience?

The empirical observations relating to the effects of ELF em fields suggest that multiples of cyclotron frequencies are important for living matter. In fact, also more general magnetic transition frequencies are expected to be important since ions can also have spin and this means that they interact with magnetic and Z^0 magnetic fields. This suggests that magnetic transition frequencies expressible could play a key role in the quantitative understanding of the physical correlates of conscious experience. In fact, one might hope of being able to characterize conscious experiences in terms of various quantum number changes occurred in the quantum jumps so that the idea that

quantum jump between initial and final quantum histories determines the contents of consciousness would be realized in a precise quantitative manner. Consider next the generalization implied by taking into account spin.

1. The charge carries of various ionic super conductors can indeed have net spin. The Cooper pairs of electronic high T_c super conductors are in $J = 2$ state which means that the spins of the Cooper pairs for spin 1 state if orbital momentum is 1. This suggest that also the Cooper pairs of bio-super-conductors could have spin $J > 0$. In case of ionic super-conductors the spin can be $J = 2$ even in relative S state. The situation for proton and neuron Cooper pairs is same as for electrons. The magnetic interaction energy $E = \mu \cdot B$ splits the energies of spin degenerate states and spins are parallel to magnetic field in ground state. Thus Earth's magnetic field is expected to cause spontaneous magnetization. It turns out that the spin flip transitions of cognitive antineutrinos in the Z^0 magnetic field of axons are fundamental for the understanding cognition and hearing in TGD framework.

2. Larmor frequency which characterizes the nuclear contribution of this interaction to energy, is related to cyclotron frequency of singly ionized atom by

$$\omega_L = g\frac{S_z}{2}\omega_c \ ,$$

where S_z is the projection of spin in the direction of magnetic field and g is Lande factor, which equals to $g = 1$ in the ideal classical case for which spin corresponds to angular momentum. For elementary fermions $g = 2$ holds true. Nuclear contribution is the dominant contribution for ions Na_+, K_+, Cl_- since electron shell is full for the ions in question. For Ca_{++} spin and magnetic moment vanishes.

3. Since Earth's magnetic field is very weak and Larmor frequencies are of same order of magnitude as cyclotron frequencies, Josephson currents might serve as harmonic perturbations inducing transitions between different spin states. The energies associated with the magnetic transitions are even multiples of Larmor frequency so that transitions changing the direction of spin of Cooper pair are induced by frequencies

$$f = (2n+1)f_c + 2\frac{\Delta S_z}{S}f_L = (2n+1+g\frac{\Delta S_z}{2})f_c \ .$$

Odd multiples of cyclotron frequency are possible in the first order perturbation theory whereas even multiples are possible only in the second order of perturbation theory. For electron $g = 2$ in excellent approximation and the Larmor frequency is very nearly identical with cyclotron frequency. The deviation $\Delta g/g = \alpha/2\pi$ in lowest order of perturbation theory ($\alpha \simeq 1/137$) and thus the frequency for $n = -1$ transition changing the direction of the spins of the Cooper pair is $f \simeq 902$ Hz, which corresponds to the time scale of nerve pulse and of memetic codon [L1]. Since electron corresponds to Mersenne prime M_{127} associated also with the memetic code, the identification or the duration of single bit of memetic codon as $1/f$ is attractive.

4. Josephson currents which can induce cyclotron resonance could also induce more general quantum jumps changing the spin direction but inducing no change in orbital degrees of freedom at Josephson frequencies not far from cyclotron frequency. Note that these transitions are possible also for neutrons since they possess magnetic moment. For proton and neutron the Lande factors are $g(p) = 5.58$ and $g(n) = -3.82$ so that the corresponding Larmor frequencies in Earth's magnetic field would be 838 Hz for proton and 570 Hz for neuron.

5. Also the total spins ($J = 0, 1, 2, 3$) associated with the Cooper pairs of Na_+, Cl_- and K_+ ions having $J = 3/2$, can flip. The corresponding frequency scale is by a factor of order A (atomic number) higher than cyclotron frequency scale since the magnetic moment of nucleus is determined essentially by the magnetic moments of nucleons with unpaired spins.

2.6 Dark counterpart of the Earth's magnetic field as carrier of ionic Bose-Einstein condensates

The original model for the effects of ELF em fields on vertebrate brain was based on the hypothesis that the ELF frequencies in question correspond to the harmonics of cyclotron frequencies of ions in the Earth's magnetic field B_E. The development of the vision about dark matter [M3] led to the realization that the macroscopic quantum phases in question are dark matter identifiable as phases with an abnormally large value of Planck constant.

TGD predicts the spectrum of Planck constant(s) (one for M^4 and one for CP_2 type quantum numbers) as integer multiples of the ordinary Planck constant. There is also a spectrum of number theoretically preferred values of Planck constant [C7] which seems to be highly relevant for the understanding of the physics of living matter [M3]. The flux quanta of magnetic field carrying dark matter as macroscopic quantum phases controlling living matter would be responsible for bio-control. The natural question whether this dark magnetic field can be identified as the magnetic field of Earth. The answer to the question came via a detection of a calculational error as progress often comes.

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

Dark matter hierarchy leads to a 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. Number theoretical arguments suggest a general formula for the allowed values of λ [C7] as $\lambda = n$ where n characterizes the quantum phase $q = exp(i\pi/n)$ characterizing Jones inclusion [C6]. The values of n for which quantum phase is expressible in terms of squared roots are number theoretically preferred and correspond to integers n expressible as $n = 2^k \prod_n F_{s_n}$, where $F_s = 2^{2^s} + 1$ is Fermat prime and each of them can appear only once. $n = 2^{11}$ obviously satisfies this condition. The lowest Fermat primes are $F_0 = 3, F_1 = 5, F_2 = 17$. The prediction is that also n-multiples of p-adic length scales are possible as preferred length scales. The unit of magnetic flux scales up as $h_0 \to h = nh_0$ in the transition increasing Planck constant: this is achieved by scalings $L(k) \to nL(k)$ and $B \to B/n$.

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

computation with Beraha number $B_n = 4cos^2(\pi/n)$ equal to Golden Mean [E9].

The natural working hypothesis is that $B_{end} = 2B_E/5$ holds true as a time average and that B_{end} defines the dark counterpart of the Earth's magnetosphere.

2.7 Identification of mind like space-time sheets as massless extremals

The so called 'massless extremals' (MEs) are basic solutions of field equations associated with Kähler action [J4]. MEs describe propagation of one-dimensional nondispersive wave with light velocity and are accompanied by light like vacuum current generating coherent photons and gravitons. Since the vacuum current behaves in a non-deterministic manner at given point of ME, it is ideal for the coding of classical information. MEs can appear also as pairs of space-time sheets such that the two space-time sheets have opposite time orientations and hence also energies so that the net energy of ME pair vanishes. MEs define a fractal hierarchy starting from elementary particle length scales and extending up to cosmic length scales. MEs have light like boundaries carrying super-canonical

One can assign to the light like boundaries of MEs representations of super-conformal and super-canonical algebras. Super-canonical symmetry is thus transformed from a cosmological symmetry to an ordinary macroscopic symmetry. Apart from small gravitational effects, super-canonical degrees of freedom commute with the translational degrees of freedom. Physical states associated with MEs correspond to Bose-Einstein condensates of collinear photons and gravitons (these degrees of freedom correspond to quaternion conformal degrees of freedom explaining elementary particle quantum numbers) having an additional super-canonical degeneracy. Super-canonical states can be interpreted as quantum holograms storing quantum information to the light like boundary of ME, which is thus analogous to the moment of big bang at the cosmological level.

The energies of BE condensed photons and gravitons come as multiples of $E = \pi/L$, where L is the length L of ME. p-Adic length scales $L_p(n) = p^{n/2}L_p$ for $p \simeq 2^k$, k power of prime, define a preferred set of lengths for MEs, and this means quantization of the fundamental transition frequencies involved with the transitions of photonic and gravitonic BE condensates as multiples of $f(p,n) = \pi/L_p(n)$. Rather amazingly, in ELF range these frequencies correspond to resonant EEG frequencies!

The super-canonical degrees of freedom commute with Poincare algebra apart from gravitational effects which means a gigantic almost-degeneracy of states. This means that super-canonical states can provide huge entanglement negentropy resources crucial for quantum computation and communication type operations as well as for cognitive representations. Thus super-canonical representations can be interpreted as quantum level articulation for the statement that TGD Universe is quantum critical quantum spin glass. Super-canonical representations clearly provide an excellent candidate for an infinite hierarchy of life forms. These life forms are labelled by three integers (k,m,n): physically interesting primes correspond to $p \simeq 2^{k^m}$, whereas k prime and m and n are integers. Perhaps it is these life forms which make mind like space-time sheets living creatures and these life forms emerge already in elementary particle length scales and become increasingly complex when the p-adic length scale increases. If so, life could be regarded as a symbiosis of these life forms with lower level life forms associated with super-conducting magnetic flux tubes.

These life forms ('mind') interact with each other, super-conducting magnetic flux tubes and ordinary matter via coherent light and gravitons and the classical gauge fields associated with MEs. MEs indeed act as receiving and sending quantum antennae and the light like classical vacuum currents associated with MEs allow to understand the classical aspects of dynamical quantum holograms and of quantum communications made possible by MEs.

MEs can also serve as Josephson junctions between magnetic flux tubes. MEs interact with super-conducting magnetic flux tube circuitry also by magnetic induction analogous to the interaction of brain's magnetic fields with SQUIDs. MEs can induce also magnetic quantum transitions.

These interaction mechanisms could explain the observed intensity windows in the interaction of ELF em fields with bio-matter [52]. Also

The natural identification of MEs as building blocks of cognitive structures leads to rather concrete model for long term memory and forces the hypothesis that MEs define an infinite hierarchy of electromagnetic life forms living in symbiosis with each other and bio-matter. The model allows to understand EEG as a direct physical correlate of mind like space-times sheets (MEs) associated with ELF selves and provides a general vision about the electromagnetic organization of brain as sensory and motor organ of higher level self. Also so called RF (radio frequency) and MW (microwave) MEs representing our mental images are crucial for the model. MEs are also crucial in the model of qualia. MEs are present also below cellular length scales and even at molecular level.

The model of qualia leads to rather detailed view about the sizes of the hierarchy of various MEs defining what might be called our electromagnetic body. It took long time to answer the question whether we should identify ourselves with the self associated with brain; with the entire body; with ELF ME having size at least of order Earth circumference; with ULF ME having size of order order light years from the fact that we have long term memories in time scale of lifetime; or with self having literally infinite size. The last two options seem to be more plausible than the first three: the illusion that we are nothing but our physical bodies is created by the fact that during wake-up state sensory input is about the region surrounding our body.

3 Many-sheeted space-time concept and topological aspects of quantum control

Many-sheeted space-time concept is crucial for TGD inspired theory of consciousness and should allow to understand the topological aspects of quantum control. Topological field quantization is perhaps the most essential aspect involved and together with the absolute minimization of Kähler action it implies rather precise correspondence between quantum and classical, including generalized Bohr rules for classical field configurations. Unfortunately, the extreme complexity of the dynamics does not allow to say much at detailed quantitative level. Quantum self-organization however comes in rescue and tells that physically interesting configurations corresponds to the asymptotic self-organization patterns selected by dissipation. This means that it should be possible to engineer asymptotic configurations by gluing together space-time sheets representing simple, highly symmetric solutions of the field equations associated with Kähler action.

3.1 How bio-systems might apply the many-sheeted space-time concept?

Many-sheeted space-time concept makes possible several exotic new physics effects. The first ideas which come into mind are antigravity machines, energy production with apparent efficiency larger than one by generation of negative energy space-time sheets, coherent motion via generation of negative energy space-time sheets having large momentum and even communication backwards in geometric time seem to be in principle possible in TGD Universe. Many-sheeted space-time makes combined with super-conductivity makes also possible mechanisms of bio-control relying on many-sheeted flow equilibrium and the strange findings challenging the notions of ionic pumps and channels [47] provide support for this notion. The application of these mechanisms might make living systems what they are.

3.1.1 Possible new physics effects related to the TGD space-time concept

TGD based concept of space-time predicts several new effects.

1. One of the basic predictions of TGD is the possibility of classical Z^0 fields having Z^0 charges as their sources. Rotating macroscopic objects should generate Z^0 magnetic fields and this suggests that the behavior of rotating objects should exhibit anomalies. A special signature of effects of this kind is parity breaking caused by the parity breaking couplings of classical Z^0 field.

2. The mere rotation of a 3-surface carrying magnetic or Z^0 magnetic fields should induce electric or Z^0 electric fields whose divergence gives rise to vacuum charge density. Charge conservation suggests that this gauge flux must flow to a second space-time sheet carrying opposite net charge.

3. In TGD the time orientation of given space-time sheet need not be the standard one and this allows the possibility of negative classical energies. If this kind of space-time sheets are created, energy production with apparent efficiency greater than unity becomes possible. At the space-time sheets with negative time orientations classical fields should propagate from future to past making in principle possible to see to the geometric future of, say, astrophysical objects.

4. A further TGD based element is related to the fact that 3-surface can be regarded as a generalization of a point like particle. This means that 3-surface behaves like single coherent whole: in particular, classical fields oscillating coherently in arbitrary long length scales are possible and can give rise to an apparent propagation of effects with infinite velocity. The notion of pair creation from vacuum generalizes. For instance, pairs of space-time sheets with vanishing total classical energy can be created from vacuum. This kind of mechanism leads to a concrete idea about how bio-systems might generate energy ("buy now, pay later").

5. In TGD classical gauge fields and gravitational fields at a given space-time sheet are extremely tightly correlated since all these fields are expressible in terms of CP_2 coordinates and their gradients. Therefore the generation of magnetic and electric fields could induce perturbations of the classical gravitational fields having amplitudes gigantic as compared to those possible in General Relativity. In this kind of situation imbeddability requirement could force the system to feed part of its gravitational flux to some other space-time sheets. These effect might make possible antigravity effects in which the gravitational flux of Earth or test body is partially channelled to some other space-time sheet. An interesting possibility is that bio-systems could apply this kind of effects.

3.1.2 Some anomalies explained by TGD based space-time picture

It has gradually become clear that there is extensive literature about anomalies possibly having TGD based explanation [G1].

1. There are several TGD based mechanisms which could contribute to the effective gravity modification effects reported by Podkletnov [60] and Schnurer [61] and Z^0 force might be involved with the effect.

2. Allais [62, 63] observed that the oscillation plane of Foucault pendulum changes during solar eclipse. NASA performed the same experiment during 1999 eclipse but the processing of the data is still going on. Z^0 MEs emitted by Sun provide a model explaining basic qualitative facts.

3. There are anomalies related to the behavior of rotating gyroscopes [64, 65] suggesting that rotating gyroscope can lose part of its weight. TGD based mechanism is following: gyroscope channels part of its gravitational fluxes to some other space-time sheets than the one

where it resides and, in the case that the receiving space-time sheet contains only very weak gravitational fields, gyroscope effectively loses part of its weight. Also the re-channelling of Z^0 fluxes might be involved.

4. There are quite puzzling observations related to the behavior of rotating stars [66, 67]. These observations are in a dramatic conflict with the standard wisdom about finite propagation velocity of signals and with the idea that classical fields propagate in future direction only. The possibility of space-time sheets with negative time orientation, and classical fields propagating from geometric future to geometric past and the possibility that 3-surfaces of even astrophysical size can behave like particle like objects, could explain these mysterious effects.

5. There are a claims about energy production with apparent efficiency larger than unity [68, 69] by machines which contain rotating magnets. TGD requires generation or existence of space-time sheet carrying charge opposite to the vacuum charge induced by the rotation. If this space-time sheet has negative time orientation, it has negative classical energy and the energy of the material space-time sheet must increase by the requirement of energy conservation.

6. Biefeld-Brown effect is one of the oldest poorly understood anomalous effects [70, 71]. What happens is that charged capacitor gains center of mass momentum in the direction orthogonal to the plane of the capacitor plates. It seems that the change of the effective gravitational weight of the capacitor based on redistribution of the gravitational and Z^0 fluxes cannot explain the entire effect. Rather, also the generation of a negative energy space-time sheet with net momentum associated with classical gauge fields could be involved. So called "massless extremals" are optimal candidates for this purpose. This mechanism might be applied by bio-systems to generate coherent motions.

3.1.3 Basic new physics mechanisms possibly applied by bio-systems

There are several candidates for new physics mechanisms applied by bio-systems.

How bio-systems are able to move coherently?

The ability of bio-systems (70 per cent of water!) to generate coherent motions is complete mystery from the point of view of standard physics describing bio-system as a soup of randomly moving atoms and molecules. The generation of negative energy space-time sheets with large net momentum compensated by opposite momentum of material space-time sheet provides a candidate for a mechanism making coherent motion possible. Negative energy space-time sheets could actually correspond to mind like space-time sheets: perhaps those representing the thought "I want to move to that direction"! If this were the case, then this mechanism could be, somewhat loosely, said to provide the basic geometric counterpart for the interaction between matter and mind.

As will be found in the chapter [J4], the generation of so called "massless extremals" provides an optimal mechanism for coherent motion. The reason is that massless extremals have maximal possible classical momentum ($E = P$ holds true) so that the generation of space-time sheet corresponding to massless extremal gives large momentum to the material space-time sheet.

Negative energies are not absolutely essential for generating coherent motions. However, if massless extremals have positive energies, the efficiency of energy usage is however very low, approximately $\beta/2$, where β is the velocity generated: something like 10^{-8} if velocity is of order one meter per second. It could quite well be that massless extremal is created only for the period of time that motion lasts: this in accordance with the idea that classical counterparts of virtual particles are in question. Since the surplus energy generated on the material space-time sheet is partially dissipated during this time interval, this mechanism requires that metabolism feeds energy to the system to compensate this loss. Thus there is no contradiction with the general wisdom about the necessity of metabolic energy feed.

Generation of metabolic energy from vacuum?

If bio-systems can generate negative energy massless extremals, a very efficient generation of metabolic energy from vacuum becomes possible in principle. This principle could be called "buy now, pay later" principle since the lifetime of negative energy space-time sheets is expected to be finite. This suggests that generation of negative energy space-time sheets is rare process and that lifetimes of negative energy space-time sheets are finite. There is a lot of anecdotal evidence about the ability of yogis and mystics to survive without eating [72]. The explanation often proposed by yogis themselves [72] is that the energy of light replaces the usual sources of the metabolic energy. Standard science sceptics of course "know" and ridicule all this but, against the background of new physics predicted by TGD, I cannot avoid asking myself whether there might be some seed of truth behind these claims.

Communication backwards in time?

Negative energy space-time sheets have negative time orientation. This suggests that classical fields could propagate backwards in time. Combining this with the TGD view about universe as four-dimensional society with mind like space-time sheets dispersed around entire many-sheeted space-time, one ends up with the idea that communication backwards in geometric time could be possible and be based on generation of propagating classical fields. We could send messages to future along positive energy space-time sheets and receive answers to our messages (probably mostly questions!) along negative energy space-time sheets. An interesting possibility is that this kind of communication in short time scales is actually basic aspect of living systems making for them possible to predict what would happen in future if no quantum jumps between histories would occur. This kind of communication could provide an alternative explanation for the causal anomalies observed by Radin and Biermann [H5, K1]. Note however that quantum jumps between quantum histories picture provides an alternative TGD based explanation for these effects. In any case, if communication backwards in time is really possible, human kind would be at the verge of an evolutionary step whose consequences are impossible to imagine.

Of course, it might be that genuine communication requires quanta, say photons. It seems that the coherent photons generated by negative energy massless extremals should possess negative energies so that the roles of the creation and annihilation type operators would be changed for photons glued to negative energy space-time sheets. If this were the case, one could also consider the possibility of communication based on negative energy photons wandering along negative energy space-time sheets.

Bio-systems as antigravity machines?

In [G2] it is found that TGD provides several mechanisms making possible what look like antigravity effects. Bio-system could get rid of part of its effective gravitational mass by feeding part of its gravitational flux to an almost empty space-time sheet different from that at which the gravitational field of Earth resides. Alternatively, bio-systems could reduce the effective strength of Earth's gravitational force by channelling part of the gravitational flux of Earth to some other space-time sheet. Also classical Z^0 fields could contribute to the effective gravitational mass and gravitational force. This is suggested by the explanation of the acceleration anomaly of spacecrafts in outer space [D6]. It this is the case then similar mechanisms could be work for Z^0 electric flux too.

3.2 Particle transfer and re-distribution of gauge fluxes between space-time sheets as a control tool in bio-systems?

3.2.1 The basic mechanisms

Particle transfer between space-time sheets is the most straight-forward control mechanism. A more refined mechanism involves redistribution of various # contacts feeding gravitational and gauge fluxes to various space-time sheets from the space-time sheet of the particle.

1. In the transfer of particle between different space-time sheets topological sum contacts, "# throats", connecting the particle to space-time sheet are split and are possibly regenerated between particle and some other space-time sheet. All that it essential that particle disappears from a given space-time sheet. As a special case one has topological evaporation defined as a transfer of particles from a given space-time sheet to "vapor phase". This transfer process can be either classical or occur by quantum jump. The transfer of macroscopic particles by topological evaporation seems however very implausible. One reason for this is that the corresponding space-time sheet has large number wormhole contacts to a large number of space-time sheets and it is extremely improbable that these contacts can split simultaneously. Also the fact that the gravitational mass of particle in vapor phase vanishes, suggests strongly that evaporation process is possible only in elementary particle length scales.

2. It is also possible that temporary join along boundaries bonds between two space-time sheets, say atomic and cellular space-time sheets, are formed and particles flow from space-time sheet to another one along the join along boundaries bond. Join along boundary bonds could be formed both non-dissipatively (Josephson currents) or by quantum jumps giving rise to dissipative currents. For this process, which simply corresponds to the formation of direct geometric contact between physical objects, there is clear evidence from everyday life and the model for bio-control and -coordination relies on Josephson currents flowing between the space-time sheets. Josephson currents could give also rise to the 'dropping' of electrons and ions from the atomic space-time sheet to larger space-time sheets. It seems that this mechanism might be the one which is realized in living matter. Also transfer of entire structures topologically condensed on given space-time sheet to a second space-time sheet is possibly along temporary join along boundaries bond formed between the two space-time sheets. This seems to happen all the time in everyday world: particle of even macroscopic size can diffuse from macroscopic objects to another one.

3. An interesting mechanism is the one in which # contacts of particle to a given space-time sheet glide to some other space-time sheet along join along boundaries bond. In this manner it would be possible to redistribute its own gravitational flux and gauge fluxes from original space-time sheet to some new space-time sheets. This would make possible for particle to reduce its effective gravitational mass. Also the gravitational force experienced by the particle would change as a result of this process: even levitation could become possible by transferring the # contacts to some nonstandard space-time sheet containing only very weak gravitational fields. This process is certainly possible: it requires only the formation of join along boundaries contact between the space-time sheet X at which particle usually feeds most of its gravitational flux and some other space-time sheet Y such that the contact can glide to Y without leaving particle space-time sheet.

3.2.2 Possible examples of particle transfer

Nondeterministic particle transfer between space-time sheets suggests a general mechanism for voluntary bio-control. For instance, particles could flow from atomic to cellular space-time sheets

along join along boundaries bonds and particle transfer would be realized as dissipative em currents between the space-time sheets.

1. The transfer of individual electrons and Cooper pairs might provide an effective tool for the control of the electronic configuration of the cells and smaller structures. The concept of exotic atom involves dropping (presumably transfer along temporary join along boundaries bonds) of electrons from atomic space-time sheet to a larger space-time sheet and the electrons at almost empty space-time sheets could be in super conducting state. In these larger space-time sheets a very effective electronic charge transfer by supra currents could be possible since dissipative effects are minimized. One could even consider the possibility of a simultaneous coherent transfer of Cooper pairs at a given level of topological condensate. The transfer of particles along join along boundaries contacts formed between space-time sheets is the most plausible mechanism of a coherent transfer. The constructive interference of Josephson currents between space-time sheets could indeed induce large transfer of particles.

2. Ions and neutral atoms could 'drop' from atomic to larger space-time sheets and form em of Z^0 super conductors at these space-time sheets. The macroscopic quantum phases formed by ions or their Cooper pairs are indeed in key role in TGD based models EEG and of sensory qualia.

3. The transfer of chemical reactants between space-times sheets provides a possible bio-chemical control mechanism. Again also the possibility of synchronous transfer induced by Josephson currents could be considered. One can consider the possibility that the transfer of most important organic molecules such as DNA sequences between space-time sheets is possible. This process provides an effective mechanism for controlling chemical reactions. For example, molecule could avoid Coulomb walls by moving on different space-time sheet and in case of a catalytic reactant this provides an effective control over the reaction. A new type of catalyst action becomes possible since catalyst molecule could overcome the purely geometric obstructions by moving on different space-time sheet ("Houdini effect") [F8]. The transfer of a molecule might be induced from $k = k_Z$ level. The motion of Z^0 # contacts in Z^0 fields at $k = k_Z$ level induces the motion of nuclei and therefore of molecule condensed on electromagnetic level $k_1 < k_Z$. If molecule enters the boundary of the condensate block k_1, it might suffer the transfer to a larger space-time sheet along join along boundaries bond.

3.2.3 Control mechanisms of motion

The transfer of particles between various space-time sheets suggests several mechanism for the control of locomotion.

1. As noticed, also macroscopic particles could flow between different space time sheets along join along boundaries bonds. The transfer of a substructure of cell size or even size of order 10^{-4} m could change the equilibrium configuration of the organ in external gravitational field. This kind of mechanism could provide a control tool for the motion of the organism.

2. Redistribution of the gravitational flux is made possible by the transfer of the ends of wormhole contacts along the join along boundaries bonds from standard space-time sheet to nonstandard ones. This makes it possible to change both the particle's effective gravitational mass and the effective gravitational field and could be involved with locomotion. This mechanism could explain the observed surprisingly large fluctuations in the value of the gravitational constant in Cavendish experiments [27].

3. Much more tricky control mechanisms can be imagined. For instance, resonant current of Ca_{++} ions between atomic and cellular space-time sheets could induce oscillatory sol-gel

transition in cytoplasm and this in turn would make possible amoeba like locomotion of a monocellular organism in which organism becomes liquid in some direction and flows that direction and then solidifies. The frequency with which sol-gel transition occurs is few ten Hz and the transfer of Ca_{++} ions is known to be involved with its control. This suggests that resonant Ca_{++} ion currents with an odd multiple of Ca_{++} cyclotron frequency in Earth's magnetic field (15 Hz) are involved with the control of sol-gel transition.

Bio-matter forms liquid crystals and sol-gel transition basically changes the liquid crystal characteristics such as the resistivity and the intensities of the spontaneously generated weak but coherent electric fields. In many-sheeted ionic flow equilibrium various (to be discussed in more detail in the sequel) ion densities at atomic space-time sheets are determined by the many-sheeted ionic flow equilibrium and are proportional k_{ion}/E, where k_{ion} denotes the ionic friction coefficient and E denotes the local electric field. It is quite possible that the transition to sol state is 'let it go' type transition in which the electric drift velocity of the ion becomes so low that a stable control by super-conducting space-time sheets is not possible anymore.

3.2.4 Metabolism in the many-sheeted space-time and the real role of ATP

The dropping of ions from atomic space-time sheets to a much larger space-time sheet, say magnetic flux tubes of Earth's magnetic field or endogenous magnetic fields, liberates the large zero point kinetic energy associated with the particle at the atomic space-time sheet. p-Adic length scale hypothesis allows to estimate the precise value of the zero point energy. The assumption that the transformation of a single ATP molecule to ADP actually involves the dropping of a hydrogen ion from the atomic space-time sheet liberating o.49 eV of zero point kinetic energy, allows to get rid of the questionable notion of high energy phosphate bond. ATP bound to magnesium atom couples the water cluster around ATP complex to the magnetic flux tubes and has thus control function rather than serving as a universal energy currency.

The dropping of ions to high n magnetic cyclotron state decaying by the emission of ELF radiation at multiples of cyclotron frequencies provides a mechanism producing EEG. It is even possible to understand the value of the neuronal resting potential in terms of this mechanism. These applications are described in [K6].

The same mechanism explains also the scaling law of homeopathy stating that the imprinted frequencies in water appear in pairs of high and low frequencies implicating the presence of each other such that the ratio of the frequencies is $f_h/f_l = 2 \times 10^{11}$. This ratio can be identified as the ratio of the zero point kinetic energy of singly ionized ion at atomic space-time sheet to its cyclotron energy in Earth's magnetic field [K5].

3.3 Motor control performed by field body

As briefly described in the introduction, the notion of field body leads to the notion of magnetic sensory canvas [M1, N1]. Sensory representations are realized at the topological field quanta of Earth's magnetic field (flux tubes or shell like field quanta) and the magnetic flux tubes emanating from brain and body accompanied by parallel MEs serve as projectors to the magnetic sensory canvas. The distance of the object of perceptive field is coded by the thickness of the flux tube emanating from the brain in turn coding for the local cyclotron frequency scale.

This picture inspires questions about how the highest level motor control exercised by the field body is realized. Is motor control practiced directly from the magnetic sensory canvas or possibly from a separate Z^0 magnetic motor canvas? Second question relates to the mechanism of the motor control. In [K6] a mechanism of motor control based on Z^0 MEs converging to brain is discussed. The classical Z^0 fields could be transformed to endogenous sounds if the living matter acts as Z^0-piezoelectric. This is in principle possible since atomic nuclei can possess anomalous

Z^0 charge and an entire hierarchy of scaled down weak physics possible corresponding to Gaussian Mersennes $(1+i)^k-1$, $k = 151, 157, 163, 167$ [F9] is possible. The control should be very high level control leaving a lot of freedom for brain to decide about the details. Perhaps internal speech is one manifestation of this control.

An important aspect of motor control is the generation of quantum entanglement: the geometric correlate for this is ME bridge. Only bound state entanglement is stable against the state preparation process associated with the quantum jump so that motor control is accompanied by the liberation of a binding energy as a usable energy. This obviously facilitates motor control. There is some evidence for the occurrence of the quantum metabolism. The regions of high neural activity in brain are not seats of high oxidative metabolism as one might expect and this has led to the puzzle about where the brain gets the energy it is believed to need [K6]. One possibility is that quantum metabolism provides the energy. Since thermal noise is expected to destroy the bound state entanglement sooner or later, one can say that thermal energy is utilized by buy now-pay later mechanism (there is definite analogy with thermal ratchets). During synesthesia left brain contains highly synchronous regions and the oxidative metabolism is 18 per cent lower than normally: in case of a normal person this would mean death [H3]. Perhaps quantum metabolism explains also this anomaly.

3.4 Scaling law of homeopathy and the role of microwaves in homeostasis

Plasmoids consisting of closed magnetic flux tube structures carrying supra currents plus atomic space-time sheets associated with them, are good candidates for primitive electromagnetic life forms. Ordinary bio-matter is assumed to self-organize around these structures and nerve circuit represents a good example of a structure resulting in this manner.

Also the magnetic life forms need energy feed to self-organize and stay awake. The basic metabolic mechanism would be the same as in the case of living matter [K6]. Energetic super-conducting ions must be somehow driven from the magnetic flux tubes to the atomic space-time sheets, where they collide with atoms, ionize them, and generate visible light in the atomic transitions giving thus rise to the observed luminous phenomena interpreted as UFOs. The ions would eventually 'drop' back to the super-conducting space-time sheet and liberate the zero point kinetic energy as a quantum of metabolic energy defining what is often referred to as a universal energy currency. Essentially identical energetic cycle of Karma would be realized also in living matter but involve a complex molecular organization and many-sheeted current circuitry responsible for the control of homeostasis. For the proton the quantum is predicted to be of order .5 eV liberated also when a single molecule of ATP is used [K6].

The realization of this primitive metabolic cycle requires the breaking of super-conductivity: some mechanism must generate join along boundaries bonds serving as bridges connecting magnetic flux tubes with atomic space-time sheets along their boundaries so that supra current leakage becomes possible. The gap energy of super-conductors, typically measured in 10^{-4} eV as a unit (corresponding to temperature measured in Kelvins), would naturally correspond to the energy needed to build up this bond (note that the temperature at the magnetic flux tubes would be much lower).

This suggests that microwave photons could induce these bridges, break super-conductivity, and induce energy feed and self-organization. A similar breaking of super-conductivity might be also involved with the driving of the super-conducting ions to the atomic space-time sheets in the living matter. Proteins could generate the needed microwave photons by coherently occurring conformational transitions. Also rotational transitions of clusters of water molecules could emit microwaves and perhaps mimic and amplify the microwaves generated by proteins.

The clusters of water molecules forming liquid crystals can mimic the conformational and

rotational spectrum of various molecules, and that the ability to reproduce the rotational frequency spectrum of the medicine molecule is an essential element of homeopathic healing. The level of self-organization of water would thus be measured by how complex mimicry it is able to perform.

Why rotational microwave energy spectrum is so important for healing, could be understood as follows. The many-sheeted current circuitry, involving atomic space-time sheets and magnetic flux tubes and also other space-time sheets, is extremely complex control structure. The continual regeneration of bridges between, say, atomic space-time sheets and magnetic flux tubes by microwaves emitted by proteins is necessary to sustain this circuitry. An important category of diseases is due to the failure to generate the bridges between super-conducting and atomic space-time sheets so that this control circuitry suffers shortcuts. Perhaps the genetic expression of some proteins responsible for the microwaves generating particular bridges fails. The medicine or its homeopathic counterpart would help to generate (or even re-establish the generation of) the microwave spectrum responsible for the generation of the lacking bridges in the circuitry.

A further piece to the puzzle comes from the scaling law of homeopathy. The law states that high and low frequencies accompany each other, the frequency ratio being $f_{high}/f_{low} \simeq 2 \times 10^{11}$ in the simplest situation (the ratio can actually vary). The TGD based interpretation is that ELF MEs are responsible for quantum entanglement in macroscopic, even astrophysical, length scales. Microwave MEs propagating effectively as mass-less particles along ELF MEs in turn induce self-organization by serving effectively as 'food' of the plasmonic life forms at the receiving end. This mechanism could be behind both the endo- and exogenous realizations of intentions as actions, that is ordinary motor actions and phenomena like remote healing and psychokinesis. Also sensory representations at the personal magnetic canvas and magnetosphere rely on this mechanism, and in this case life forms are mental images getting at least partially their metabolic energy from brain.

As a matter fact, also other than microwaves photons, for instance IR and visible photons are predicted to be important for the self-organization of living matter but it seems that microwave photons are of special importance.

3.5 Bio-systems as conscious holograms

The idea that brains, bio-systems, and perhaps the entire Universe are some kind of holograms has long history. TGD Universe is indeed quantum gravitational hologram in a well-defined sense but this does not yet allow development of a detailed model of bio-system as a hologram. What seems to be needed is the generalization of ordinary hologram to that of a conscious hologram.

A sequence of small steps of progress in the understanding the endogenous and exogenous realizations of intentionality finally led to a concrete vision about what conscious holograms might be. Ironically, the crucial ideas came from the modelling of homeopathy, Fatima miracle, UFOs, crop circles, and other anomalous phenomena rather than from orthodox science accepted by skeptics (see the relevant chapters of [14]). Topological light rays (MEs), the role of microwaves in the breaking of super-conductivity in many-sheeted space-time, and scaling law of homeopathy stating that important biological frequencies appear in pairs of low and high frequencies, play key roles in the realization. The vision about living system as a conscious hologram looks roughly like follows [K5].

1. The points of the hologram correspond to space-time sheets representing some structural units of bio-system with size of considerably smaller than the wavelength associated with high frequency MEs (from the requirement of effective point likeness). Several low frequency MEs from external world converge to these points like light rays. Low frequency MEs can connect also different points of the hologram and one could also speak of 'self-hologram'. Brain and body are basic examples about self hologram. Low frequency MEs serve as quantum entanglers and guarantee both classical coherence and macroscopic and macro-temporal

quantum coherence.

2. High frequency (microwaves, IR, and visible light) MEs propagating like massless particles inside low frequency MEs (ELF and radio waves) fuse at the points of the hologram, and the classical fields associated with high frequency MEs interfere in these regions. The resulting classical field induces the leakage of supra currents from magnetic flux tubes to the atomic space-time sheets, and this stimulates self-organization and metabolic cycle and generates mental image. This the counterpart for the generation of ordinary hologram. The scaling law of homeopathy relates the high and low frequencies and makes the model quantitative.

3. The points of hologram correspond to more or less identical structural basic units such as genome, cells, and basic information processing units of cortex having size of order one millimeter. At the level of magnetospheric consciousness different organisms of the same species and even body parts can correspond to points of conscious holograms. The reason why bio-systems consist of similar basic units is that this makes possible conscious holograms and stereo consciousness.

4. Ordinary hologram gives rise to 3-D image. In case of a conscious hologram the fusion of mental images by quantum entanglement gives rise to the formation of what might be called stereo-consciousness and has classical and quantum coherence and the formation of ordinary many-sheeted hologram as physical correlates.

5. The notion of conscious hologram unifies a large number of separate ideas by providing a model for homeostasis and hardwave of consciousness. Also the models for a plethora of anomalous phenomena like homeopathy, remote mental interactions, UFOs, crop circles, and several anomalies related to free energy, can be understood in this general framework. The picture is consistent with the basic empirical facts usually taken as a support for the localization of consciousness in brain and localization of mental functions to various parts of brain. The units of conscious hologram receiving information from external world behave effectively as functional units although the conscious experience is shared by the units of hologram connected by MEs to these units.

In particular, if some part of conscious hologram is stimulated strongly, the experience associated with the entire hologram is determined by this part of the hologram. Neurons can have complex experiences differing from our own experiences only in that stereo aspect is absent. Emotions are experienced by all cells of body: whereas primary sensory organs feed conscious information to sensory cortex, limbic brain acts as a primary emotional organ feeding conscious information to body, where emotions are not only expressed but also felt. Also the hypothesis about the realization of sensory representations at magnetic magnetic body and magnetosphere fits nicely with this picture: the new element is that microwave MEs propagating along EEG MEs induce self-organization at the magnetic body and magnetosphere.

The findings about bio-holograms [39] give support for the notion of concious hologram. The pairs of frequencies involved corresponds low frequency of about kHz and high frequencies which in visible region. What happens is that simultaneous electrical stimulation of the inner ear affects the Kirlian image taken from the finger tip, and one can even deduce hologrammic image of the inner ear from the Kirlian image.

4 Quantum tools for bio-control and -coordination

Coordination and control are the two fundamental aspects in the functioning of the living matter. TGD suggests that at quantum level deterministic unitary time evolution of Dirac equation corresponds to coordination whereas time evolution by quantum jumps giving rise to self-organization

corresponds to quantum control. The fractal hierarchies of MEs and super-conducting magnetic flux tubes and bio-matter at atomic space-time sheets would be the basic building blocks of the control system. The basic control structure would be many-sheeted ionic current circuitry: the currents would flow as supercurrents at magnetic flux tubes and as ohmic currents at atomic space-time sheets. MEs would interact with the super currents via magnetic induction and by forming Josephson junctions between magnetic flux tubes. An important mechanism of control would be 'let it go' mechanism in which the control of atomic space-time sheets would fail for a moment: this would be like opening the faucet for a moment.

Supercurrents and non-dissipative Josephson currents associated with weakly coupled super conductors would be the key element in coordination whereas oscillating super currents and Josephson currents at resonance frequencies inducing quantum jumps and thus 'waking-up' sub-selves and initiating quantum self-organization, would be crucial for control.

This view allows to consider more detailed mechanisms. What is certainly needed in the coordination of the grown-up organism are biological clocks, which are oscillators coupled to the biological activity of the organ. Good examples are the clocks coordinating the brain activity, respiration and heart beat [32]. For example, in the heart beat the muscle contractions in various parts of heart occur in synchronized manner with a well defined phase differences. Various functional disorders, say heart fibrillation, result from the loss of this spatial coherence. For a control also biological alarm clocks are needed. An alarm clock is needed to tell when the time is ripe for the cell to replicate during morphogenesis. Some signal must tell that is time to begin differentiation to substructures during morphogenesis: for example, in case of the verterbrates the generation of somites is a very regular process starting at certain phase of development and proceeding with a clockwise precision.

4.1 Many-sheeted ionic flow equilibrium as a fundamental control mechanism

Many-sheeted ionic flow equilibrium in which supra currents at magnetic flux tubes flow to atomic space-time sheets where they run as ohmic currents, and back, is very attractive quantum control mechanism and the empirical facts discussed in the [J1, J2, J3] provide strong support for this mechanism.

1. The mechanism requires the presence of coherent electric fields at atomic space-time sheets, which can however be very weak. The liquid crystal property implying electret property guarantees this. Current conservation relates the ionic densities in super-conducting magnetic flux tube circuitry and non-super-conducting atomic parts of the circuitry. For the simplest circuit one has in equilibrium $I_{super} = n_{super} v_{super} = I_{atom} = n_{atom} v_{atom}$, which gives

$$n_{atom} = n_{super} \times \frac{v_{super}}{v_{atom}} \quad .$$

The atomic drift velocity v_{atom} relates to the electric field E at the atomic space-time sheet and to the coefficient k_{ion} characterizing the proportionality of the ionic friction force to velocity

$$v_{atom} = \frac{E}{k_{ion}} \quad .$$

The weaker the electric field and the stronger the ionic friction, the stronger the amplification of the super-conducting ionic density to the ionic density at atomic space-time sheet is. Therefore very weak super-conducting ion densities can perform effective control.

2. v_{super} is typically proportional to the magnetic quantum number characterizing super current and the interaction of the current circuits with the external magnetic fields, in particular those associated with MEs, can change the value of the super-conducting ionic velocity v_{super} (magnetic flux is related to current via $\Phi = LI$ modulo elementary flux quantum). This means that MEs can control the densities of the ions at atomic space-time sheets. If the electric field and friction coefficient remain constant paramaters, the values of the ion densities at atomic space-time sheets are quantized by the quantization of the magnetic quantum number, typically integer. This might provide an empirical test for the mechanism.

3. The rates for the quantum transitions for Bose-Einstein condensates of super-conducting ions are proportional to N^2, where N is the number of ions. This means coherence and amplification. This could in fact lead to quantum phase transitions in which all ions experience the same quantum transition. In particular, magnetic quantum phase transitions suggest itself and they could make possible what might be called endogenous nuclear magnetic resonance (NMR) spectroscopy: the generated coherent light would Bose-Einstein condense on MEs and generate conscious experience and give rise to chemical qualia. Perhaps even other than magnetic quantum phase transitions could occur. One cannot exclude the possibility that even DNA and proteins could form super-conducting BE condensates (although the large number of internal almost degenerate states perhaps hinders this) and MEs could thus control their conformations by inducing conformation changing transitions. This would make possible very effective bio-control by controlling the conformations of enzyme molecules determining their catalytic properties.

4. By their small mass implying high mobility, electrons play an important role in the control of the conformations of bio-molecules. Electronic flow equilibrium between molecular and atomic space-time sheets could be responsible for the quantum control of the molecular conformations. The electronic supra-currents associated with DNA and protein space-time sheets could be directly controlled by the interaction with MEs; the supra-currents (depending on magnetic quantum numbers) would in control the distribution of electrons at the atomic space-time sheets, which in turn would determine the conformation of the bio-molecule. MEs could thus induce collective phase transitions between various molecular conformations. This mechanism seems more plausible than the partipancy of large bio-molecules to the many-sheeted ionic flow.

   Immune system would guarantee that the frequencies associated with the transitions inducing changes of all protein and DNA conformations so near to each other so that MEs can induce these collective phase transitions efficiently. For not quite identical invader protens these frequencies are too different and they cannot participate to the coherent phase transitions. The recognition of the invader proteins could be based on the very fact that they do not respond to the same frequencies as the own proteins of the organism.

4.2 Self-hierarchy and hierarchy of weakly coupled super conductors

The realization that bio-systems are full of macroscopic quantum phases led to the general idea about the dynamical realization of the self-hierarchy as a master-slave hierarchy formed by weakly coupled super conductors. The formation of join along boundaries bonds between the space-time sheets at different levels of the self hierarchy makes it possible for a higher level self, not only to experience what it is to be the lower level self, but also to perform quantum control. Join along boundaries bonds give rise to Josephson junctions carrying Josephson current characterized by Josephson frequency.

The first proposal for the mechanism of bio-control was based on the idea was that when Josephson frequency equals to the energy difference of the quantum states of the charge carriers

localized in either super conductor, resonant transfer of ions between super conductors occurs. If the localized states in question result from magnetic confinement, energy difference corresponds to a multiple of the cyclotron frequency of the charge carrier. Also supra currents and ohmic currents (above critical flow velocity) could flow through the join along boundaries contacts and are expected to be also important in bio-control. The later work did not lead to any detailed realization of this model and led to proposal for a model of quantum bio-control which makes sense only in the full conceptual framework provided by TGD.

The observed effects of various ELF fields on brain can be indeed understood if cyclotron frequencies in an endogenous magnetic field $B_{end} = .2$ Gauss are in question. This magnetic field is not equal to the magnetic field of Earth as I erratically believed for a long time but relates to the nominal value $B_E = .5$ Gauss of the Earth's magnetic field by the scaling $B_{end} = 2B_E/5$. The interpretation of B_{end} as a dark counterpart of the Earth's magnetic field carrying dark ionic Bose-Einstein condensates turns out to be natural in TGD framework.

This leads to a beautiful general realization of quantum control. Destructive interference of supra currents leads to a large net Josephson current and various biological clocks could rely on this mechanism. When reference supra current representing the expected sensory input and a current representing real sensory input and flowing in parallel manner in weakly coupled super conductors, are sufficiently near to each other, constructive interference of the Josephson currents occurs and can give rise to a synchronous firing. This makes possible conscious comparison circuits. Conscious novelty detectors can be build easily from comparison circuits using inhibitory and excitatory synaptic connections.

4.2.1 Simple model for weakly coupled super conductors

Several kinds of Josephson currents between cell interior and exterior are possible. Soliton sequences are the simplest solutions of Sine-Gordon equation for the Josephson junctions associated with a linear structure such as axon idealized as an infinitely long and thin cylindrical surface and are mathematically equivalent with a rotating gravitational pendulum.

The most general formulation starts from the Klein-Gordon equation for the order parameters Ψ_i, $i = 1, 2$ for the super-conductors coupled linearly to each other in the junction

$$\begin{aligned} D\Psi_1 &= m^2\Psi_1 + m_{12}^2\Psi_2 \ , \\ D\Psi_2 &= m^2\Psi_2 + m_{12}^2\Psi_1 \ , \\ D &= (\partial_\mu + iZeA_\mu)(\partial_\mu - iZeA_\mu) \end{aligned} \tag{1}$$

Here m denotes the charge of the super-conducting particle (say Cooper pair) and m_{12}^2 is real parameter characterizing the coupling between the super conductors. A_μ denotes electromagnetic vector potential associated with the super conductors.

Weakly coupled super conductors are assumed to possess cylindrical symmetry and can regarded as inner and out cylinder with Josephson junctions idealized with smooth distribution of them. If ME acts as Josephson junctions this asumption is exact. Weak coupling means that that the densities of charge carriers are same at the two sides of the junction in a good approximation:

$$\Psi_i = \sqrt{n} exp(i\Phi_i) \ , \ i = 1, 2 \ . \tag{2}$$

Under these assumptions one obtains for the phase difference $\Phi \equiv \Phi_1 - \Phi_2$ the Sine-Gordon equation with a coupling to the vector potential

$$\partial^\mu \left[\partial_\mu \Phi - q\Delta A_\mu\right] = m_{12}^2 sin(\Phi) \tag{3}$$

ΔA_μ denotes the difference of the vector potential over the junction. q denotes the charge of the super-conducting charge carrier.

Note that Lorentz gauge condition

$$\partial_\mu A^\mu = 0 \tag{4}$$

does not trivialize the coupling to the vector potential since the equation holds true only in 3-dimensional surface defining the junction and the contribution from the direction of the normal is not present.

Josephson current J_J can be identified as the divergence of the 4-current $j_\mu = Ze\rho = Ze\Psi^*(\partial_\mu^{\rightarrow} - \partial_\mu^{\leftarrow})\Psi$ at the either side of the junction.

$$J_J = \partial_\mu J^\mu = Ze \times \frac{n}{m} \times m_{12}^2 sin(\Phi) \ . \tag{5}$$

The Josephson current per unit length of axonal membrane of radius R and thickness d is given by

$$J = Ze \times \frac{n2\pi Rd}{m} \times m_{12}^2 sin(\Phi) \ . \tag{6}$$

The parameter m_{12}^2 is analogous to the inverse of the magnetic penetration length squared ($\hbar = c = 1$) for the super-conductors involved.

$$m_{12}^2 = \frac{1}{\Lambda^2} \ . \tag{7}$$

If one can regard the Josephson junction region as a defect in a super-conductor, Λ is apart from a numerical constant of order unity equal to the thickness of the Josephson junction. In the case of the cell membrane this would mean that the small oscillations associated with the Josephson junction have frequencies of order 10^{16} Hz and correspond to quanta with energies of order 100 eV.

The covariant constancy conditions

$$\begin{aligned} \partial_t \Phi &= ZeV(t,z) \ , \\ \partial_z \Phi &= ZeA_z(t,z) \ . \end{aligned} \tag{8}$$

are mutually consistent only if the electric field in the axial direction vanishes. They are not however consistent with the right hand side of the equation and only one of the conditions can be satisfied. The condition effectively reduces the equation to an ordinary differential equation. Of course, one cannot assume the condition for general solutions.

For a constant potential difference V_0 the Josephson current is sinusoidal for $\partial_t \Phi = ZeV_0$ ansatz with the basic frequency given by $\omega = eV_0$. An exact treatment replaces the sinusoidal time dependence of Φ with the time dependence of the angle coordinate of gravitational pendulum so that higher harmonics are involved. In case of cell membrane $V(t)$ is typically a sum of constant part and time dependent part giving rise to frequency modulation of the basic Josephson current:

$$\omega(t) = eV = eV_0 + eV_1(t) \ .$$

Entire hierarchy of frequency modulations is possible since also eV_1 can be frequency modulated by Josephson currents.

4.2.2 Josephson junctions and interaction with coherent photons

Josephson junctions between two electronic super conductors make possible the coupling of super conductors to coherent photons, which in TGD based biology are emitted by various linear structures (in case that these structures contain space-time sheet representing massless extremals). The macroscopic description of Josephson junction is based on the current-voltage relation [55, 30]

$$\begin{aligned} I &= I_0 sin(\phi) + C_j \frac{dV}{dt} + \frac{V}{R_j} \ , \\ \phi &= \int 2eV dt \ . \end{aligned} \tag{9}$$

Critical current I_0, the shunt resistance R_j and the capacitance C_j are macroscopic parameters in the description of the Josephson junction. Note that C_j is essentially kinematical parameter determined by the geometry of the Josephson junction. ϕ is equal to phase difference between the weakly coupled super conductors and $I_0 sin(\phi)$ is the Josephson current giving rise to the typical stepwise current-voltage characteristic. I_0 can be related to the microscopic properties of the Josephson junction.

A good candidate for a Josephson junction is cell membrane. In this case Josephson current corresponds to a protein connecting the lipid layers of the cell membrane. If Cooper pairs tunnel, I_0 is proportional to density of Cooper pairs at space-time sheet involved and to the rate for the tunnelling of single Cooper pair. If single electron tunnelling is in question, I_0 is proportional to the rate of single electron tunnelling and the density of the unpaired electrons. It is in principle quite possible to estimate I_0 for, say, proteins connecting cell membrane.

In case that there are several parallel Josephson junctions the current contains sum over various Josephson currents and destructive interference between the Josephson currents becomes possible. Quantum criticality suggests that destructive interference might serve as a biological alarm clock based on the interference of some reference current and a current describing input to system and representing perhaps sensory data. Dissipation would lead to the reduction of the reference current but the ringing of the clock induced in this manner would regenerate the reference current automatically. Second possibility is a comparison circuit based on parallel supra currents of equal magnitude flowing in weakly coupled super conductors. If the currents are in the same phase, constructive interference of Josephson currents associated with various Josephson junctions occurs and can in turn lead to large effects, such as neural firing.

Josephson junctions can be realized as join along boundaries bonds and the potential difference between the coupled super conductors characterizes the link as far as the electromagnetic coupling is considered: the energies of photons emitted by the Josephson current are multiples of the potential difference eV: $E = neV$ [30, 55]. For cell membrane eV is about $eV \simeq .05$ eV.

4.2.3 Simplest solutions of Sine-Gordon equation

Free Sine-Gordon equation resulting, when the coupling to the em field can be neglected, gives a good view about the solutions of full equation. In cylindrical geometry Sine-Gordon equation becomes effectively 2-dimensional under rather natural conditions. This is rather nice since two-dimensional Sine-Gordon equation is completely integrable and thus allows an infinite number of conserved charges[21].

Sine-Gordon equation allows two kinds of vacua. The vacua of first type correspond to $\Phi = 2n\pi$ ground state configuration and vacua second type to $\Phi = (2n+1)\pi$. The small perturbations around these vacua correspond to massive 1+2 dimensional free field theory with field equations

$$D\Phi = \epsilon \frac{1}{\Lambda^2} \Phi \ ;$$

$$
\begin{aligned}
D &= \partial_t^2 - \nabla^2 \ , \\
\epsilon &= -1 \ \text{for} \ \Phi = n2\pi \ , \\
\epsilon &= 1 \ \text{for} \ \Phi = (2n+1)\pi \ . \qquad (10)
\end{aligned}
$$

In the language of quantum field theory, the small perturbations around $\Phi = n2\pi$ describe particle with mass squared $m^2 = \frac{1}{\Lambda^2}$ whereas the small perturbations of the $\Phi = (2n+1)\pi$ vacuum describe tachyons with negative mass squared $m^2 = -\frac{1}{\Lambda^2}$. Therefore these vacua will be referred to as time like and space like respectively.

One might argue that the space like vacua are unstable in the case that the continuous sheet of the Josephson junctions consists actually of discrete Josephson junctions, whose dynamics is given by the differential equation

$$\frac{d^2\Phi}{dt^2} = -\frac{sin(\Phi)}{\Lambda^2}$$

allowing only $\Phi = n2\pi$ as stable ground state. For MEs acting as Josephson junction the situation is different. On the other hand, the ground state at which soliton generation is possible should be quantum critical and hence very sensitive to external perturbations. Note that time like and space like sectors in axonal portion of neuron are permuted by a duality transformation $z \leftrightarrow vt$ (v=c=1), $\Phi \rightarrow \Phi + \pi$, which is exact symmetry of the 1+1-dimensional Sine-Gordon equation.

The propagating waves are of form $sin(u)$, where one has

$$
\begin{aligned}
u &= \gamma_P(t - \frac{v_P z}{v^2}) \ , \ \text{time like case} \\
u &= \gamma_P(z - v_P t) \ , \ \text{space like case} \\
\gamma_P &= \sqrt{\frac{1}{1-(\frac{v_P}{v})^2}} \ . \qquad (11)
\end{aligned}
$$

Here v_P is the velocity parameter characterizing the boost. The frequency of these small propagating oscillations (planewaves) is in two cases given by

$$
\begin{aligned}
\Omega &= \frac{\gamma_P v}{\Lambda} \ , \ \text{time like case} \ , \\
\Omega &= \frac{\gamma_P v_P}{\Lambda} \ , \ \text{space like case} \ . \qquad (12)
\end{aligned}
$$

The frequency is very high for time like waves, of order 10^{10} Hz and therefore a typical time scale for the conformational dynamics of proteins. In space like case the phase velocity of the propagating waves is $v_P < v$ and frequencies are small and one could consider the possibility of identifying these oscillations as propagating EEG waves. For the time like excitations phase velocity is $v_p = v^2/v_P > v$ and larger than light velocity. For ordinary elementary particles the situation is same but since phase velocity is in question, there are no interpretational problems.

One-dimensional solutions of the Sine-Gordon equation give quite satisfactory picture about the situation as far as the physical interpretation is considered. The simplest solutions of this type correspond to solutions depending on time or spatial coordinates only. For time like vacua one-dimensional solutions depend on time only: note that these solutions are possible for arbitrary geometry of the Josephson junction. For space like like vacua one-dimensional solutions are possible in the axonal portions of the neuron: the simplest one-dimensional solutions depend on the axonal coordinate z only.

Field equations reduce to the equations of motion for gravitational pendulum:

$$\frac{d^2\Phi}{du^2} = -\frac{1}{\Lambda^2} sin(\Phi) \ . \tag{13}$$

$u = vt$ holds true in time like case ($v = c \equiv 1$ is good approximation). $u = z$ holds true in space like case (in this case equation makes sense for axonal portions only). Energy conservation for the gravitational pendulum gives

$$\frac{1}{2} v^2 (\frac{d\Phi}{du})^2 + \frac{v^2}{\Lambda^2} [1 - cos(\Phi)] = K \frac{2v^2}{\Lambda^2} \ , \tag{14}$$

where K is dimensionless constant analogous to energy. There are two kinds of solutions: oscillating solutions ($K < 1$) and rotating solutions ($K > 1$): single soliton solution corresponds to $K = 1$.

One can integrate the conservation law for energy to give the time/spatial period of oscillation or rotation (T/λ). For oscillating solutions one has

$$T = \frac{\lambda}{v} = \frac{\Lambda}{v} \int_{-\Phi_0}^{+\Phi_0} d\Phi \frac{1}{\sqrt{2\,[-cos(\Phi_0) + cos(\Phi)]}} \ . \tag{15}$$

Here Φ_0 is maximum value of the phase angle for oscillating solution. For the rotation period one obtains

$$T = \frac{\lambda}{v} = \frac{\Lambda}{v} \int_0^{2\pi} d\Phi \frac{1}{\sqrt{(\frac{d\Phi}{dt})^2(\Phi = \pi) + 2\,[1 - cos(\Phi)]}} \ . \tag{16}$$

By Lorentz-boosting space like axonal solutions to move with velocity v_p one obtains propagating soliton sequences.

Sine-Gordon equation is completely integrable and thus allows an infinite number of conserved charges. In quantum theory the eigenvalues of mutually commuting charges characterize the quantum state and these charges are basic quantum observables. Does it make sense to quantize Sine-Gordon and could one characterize the state of the axonal membrane in terms of these charges? Here one must point out the similarity to the ideas of Nanopoulos [35], who speculates with the possibility that certain 2-dimensional conformal field theory characterizes the state of micro-tubule and the infinite number of conserve charges characterize the information content of the micro-tubule. It is perhaps also worth of mentioning that the quantum group $SU(2)$ appears in the quantization of the Sine-Gordon equation [22]: could quantum groups have important applications in biology?

4.2.4 Modulation hierarchy of Josephson currents

The modulation of the Josephson current is induced by the oscillatory time varying part of the potential difference superposed to constant part. The oscillatory time dependent part can be generated by an oscillatory em current through the cell membrane or running from cellular space-time sheet to some other space-time sheet via join along boundaries bonds. Also currents which run between different levels of the p-adic lengths scale hierarchy and could flow along join along boundaries bonds connecting space-time sheets at different levels of the hierarchy.

One can consider also frequency modulations of frequency modulations of .... forming a hierarchical structure analogous to the abstraction hierarchy and giving rise to abstraction hierarchy

of senses. This would explain the effects of various frequency modulated signals to brain. The effects of external em field to bio-system are expected to be largest when the frequency modulated signal is as nearly as possible equal to the modulating part of the membrane potential. Modulation hierarchy can be realized if the em current yielding modulation at given level is itself Josephson current so that entire hierarchy of Josephson junctions is implied. In this case modulating current cannot be between cell interior and exterior however but between cell interior or interior and some other space-time sheet at same or different p-adic hierarchy level. Josephson currents induce oscillatory changes of total charges of space-time sheets involved and these in turn induce oscillatory modulations of the potential differences between various Josephson junctions.

The hypothesis that modulation hierarchy corresponds to the p-adic hierarchy of space-time sheets suggests that Josephson currents in question are between space-time sheet representing different hierarchy levels. Josephson current flow along the join along boundary contacts connecting these space-time sheets ('biofeedback'). The current would change the density of charged particles at cellular space-time sheet and induce change of the membrane potential proportional to the Josephson current in question. An essential point is that the two space-time sheets in question ought to be super conducting.

4.3 General mechanism making possible biological clocks and alarm clocks, comparison circuits and novelty detectors

Weakly coupled super conductors and quantum self-organization make possible very general models of biological clocks and alarm clocks as well as comparison circuits and novelty detectors.

The Josephson junction between two super-conductors provides a manner to realize a biological clock. Josephson current can be written in the form [28]

$$\begin{aligned} J &= J_0 sin(\Delta\Phi) = J_0 sin(\Omega t) \ , \\ \Omega &= ZeV \ , \end{aligned} \tag{17}$$

where Ω is proportional to the potential difference over the Josephson junction. Josephson current flows without dissipation.

In BCS theory of super-conductivity the value of the current J_0 can be expressed in terms of the energy gap Δ of the super conductor and the ordinary conductivity of the junction. When the temperature is much smaller than critical temperature, the current density for a junction is given by the expression [28]

$$J_0 = \frac{\pi}{2e}\frac{\sigma_s \Delta}{d} \ . \tag{18}$$

Here σ_s is the conductivity of the junction in the normal state assuming that all conduction electrons can become carriers of the supra current. d is the distance between the super conductors. The current in turn implies a position independent(!) oscillation of the Cooper pair density inside the two super conductors. By the previous arguments the density of the Cooper pairs is an ideal tool of bio-control and a rhythmic change in biological activity expected to result in general. Josephson junctions are therefore good candidates for pacemakers not only in brain but also in heart and in respiratory system.

In the presence of several parallel Josephson junctions quantum interference effects become possible if supra currents flow in the super conductors. Supra current is proportional to the gradient of the phase angle associated with the order parameter, so that the phase angle Φ is not same for the Josephson junctions anymore and the total Josephson current reads as

$$J = \sum_n J_0(n) sin(\Omega t + \Delta\Phi(n)) \ . \quad (19)$$

It is clear that destructive interference takes place. The degree of the destructive interference depends on the magnitude of the supra currents and on the number of Josephson junctions.

There are several options depending on whether both super conductors carry parallel supra currents or whether only second super conductor carries supra current.

1. If both super conductors carry supra currents of same magnitude but different velocity, the phases associated with the currents have different spatial dependence and destructive interference occurs unless the currents propagate with similar velocity. This mechanism makes possible comparison circuit serving as a feature detector. What is needed is to represent the feature to be detected by a fixed supra current in the second super conductor and the input as supra current with same charge density but difference velocity. The problem is how the system is able to generate and preserve the reference current. If case that feature detector 'wakes-up' into self state when feature detection occurs, the subsequent quantum self-organization should lead to the generation of the reference current representing the feature to be detected.

2. If only second super conductor carries supra current and of this supra current for some reason decreases or becomes zero, constructive interference occurs for individual Josephson currents and net Josephson current increases: current causes large gradients of Cooper pair density and can lead to the in-stability of the structure. When the supra current in the circuit dissipates below a critical value, in-stability emerges. This provides a general mechanism of biological alarm clock.

   Assume that the second super conductor carriers a supra current. As the time passes the reference current dissipates by phase slippages[29, 28]. If the reference current is large enough, the dissipation takes place with a constant rate. This in turn means that the Josephson current increases in the course of time. When the amplitude of the Josephson current becomes large enough, the density gradients of the charge carriers implied by it lead to an instability of the controlled system: the clock rings. Since the dissipation of (a sufficiently large) Josephson current takes place at constant rate this alarm clock can be quite accurate. It will be found that a variant of this mechanism might be at work even in the replication of DNA. The in-stability itself can regenerate the reference current to the clock. If the alarm clock actually 'wakes-up' the alarm clock to self state, self-organization by quantum jumps must lead to an asymptotic self-organization pattern in which the supra current in the circuit is the original one. Actually this should occur since asymptotic self-organization pattern depends only weakly on the initial values.

3. Novelty detector can be build by feeding the outputs of the feature detectors to an alarm clock circuit. In alarm clock circuit only the second super conductor carries supra current, which represents the sum of the outputs of the feature detectors. Since the output of a feature detector is non-vanishing only provided the input corresponds to the feature to be detected, the Josephson current in additional circuit becomes large only when the input does not correspond to any familiar pattern.

4.4 Biological quantum control circuits

Various macroscopic quantum phases such as the BE condensate of # contacts, electronic and ionic Cooper pairs, ions and even neutrino Cooper pairs and atomic Cooper pairs forming Z^0 super

conductors provide a rich repertoire of possible realizations for comparison circuits, biological clock and alarm clocks as well as feature- and novelty detectors. Note that # contacts are expected to appear in all biologically relevant length scales.

1. Biological clock consists of parallel Josephson junctions between two subsystems, which could be organs or organelles or even bio-molecules. There is a sinusoidally varying Josephson current between the two super-conductors in question. Note that also propagating waves are possible. For the ordinary electronic super conductor, the current for a single junction is given by $J \propto (\Delta\sigma/\Omega)sin(\Omega t)$. The value of the conductivity σ depends on the properties of the Josephson junction. It is rather remarkable, that for low frequencies Ω the current increases: this could correlate with the fact that low frequency EEG amplitudes are larger than high frequency amplitudes if EEG frequencies indeed correspond to Josephson frequencies for ionic Josephson currents.

2. Possible biological applications are feature- and novelty detection in brain: very complicated logical circuits waking up some sub-self under given conditions are possible and can give rise to complicated program like behaviors in which wake-up leads to self-organization process. Simpler applications are clocks and alarm clocks with brain (EEG and wake-up cycle) and heart beat and respiratory system. The additional bonus of the Josephson clock is that the nerve pulses generating the muscle contraction in the heart beat and respiration cycle can be generated at the second half of the clock period only so that very sharp control is achieved. These examples suggests that Ω is very small in general. There exist direct evidence for the Josephson clock at the muscle level: the rest length of the muscle is known to oscillate with a frequency of about 50 Hz. Josephson clock implies a periodic variation of the density of the charge carriers inside the muscle and the sensitivity of the stable length of the muscle to the density of the charge carriers implies the oscillatory behavior of the muscle length, too. Oscillation could directly relate with the oscillation of the muscle cell resting potential with this frequency such that nerve pulses are generated when resting potential is near to its minimum.

3. The spatial dependence of the order parameter provides a tool for the spatial synchronization. The large scale variations constant in the length scale of an individual biological alarm clock imply that the clocks have nonrandom lag with respect to some reference clock. This means that the process started by the ringing of the clocks propagates in an orderly fashion. As far as morphogenesis is considered, the really nice feature of the alarm clock mechanism is that the only information stored is the time lapse to the ringing of the clock and this can be stored, when the clock is created rather than being stored in the DNA of the organism. The same can be said about the phase information needed for a spatial synchronization. What happens is the feeding of negentropy to the clock from the environment, when the reference current is generated.

4. Binary structures are very general in bio-systems and seem to be associated with pairs of p-adic primes whose p-adic length scales are related by a factor of two. There are amazingly very many of them in the p-adic length scale range relevant to bio-systems (DNA double helices, cell membranes, epithelial sheets, bi-layered structures of cortex). Typically these structures consist of a large number of smaller subunits (lipids in case of lipid layers of cell membrane, cells in case of the epithelial sheet, larger groups of cells in case of structures of cortex). These structures are optimal comparison circuits and thus also feature- and novelty detectors as well as clocks and alarm clocks. What is needed is that the components of the bilayered structure are weakly coupled super conductors of some kind.

4.5 A quantitative model for the bio-control performed by # contact BE condensate

Since # contacts are expected to form BE condensates at all space-time sheets of the topological condensate, they provide an ideal tool for the control and coordination in bio-systems. If bio-systems correspond to 4-surfaces, which are small deformations of the vacuum extremals of Kähler action, the idea about # contacts as the master and the geometry and 3-topology as slave is very attractive. For the coordination biological clocks are need. # contact BE condensate is very much like super conductor and Josephson junctions with an oscillating phase difference as well as propagating waves are possible. For bio-control localized kinks, solitons, representing a localized increment of the phase angle Ψ or Φ by a multiple of 2π could be crucial. These kinks should be created by a process analogous to the phase slippage process.

It is highly desirable to find a quantitative formulation for the coupling between # contact BE condensate and 3-geometry in terms of a variational principle. This kind of formulation is indeed possible and is obtained from the free action associated with the # contact condensate by writing it in the induced metric for the boundary of the space-time surface regarded as a dynamical object.

4.5.1 Formulation of the model

The physical constraints on the action are as follows:

1. The field equations for the # contact order parameter describe charged bosonic particles with mass m of order $m \sim 1/L(n)$, where $L(n)$ is the characteristics length scale associated with the condensate level n. This amounts to the addition of a term of form

$$L_0 \;=\; \bar{\psi}(-D^\mu D_\mu - m^2)\psi\sqrt{g} \;, \tag{20}$$

   to the action. Here D_μ is the covariant derivative in the induced metric including also the term giving coupling to the difference of the classical electromagnetic gauge potentials associated with the two space-time sheets involved. If coherent photons are present, a similar term associated with the topologically condensed coherent photons on the two space-time sheets, is present. Index raising is performed using the induced metric regarded as a dynamical variable.

2. The total electromagnetic charge of the 3-surface is fixed, so that the total charge associated with the BE condensate is $N(\#)$ and is conserved. This condition is included as a Lagrange multiplier term

$$S_1 \;=\; \int dt\lambda_1(t)\left[\int \bar{\psi}(i\partial_t^{\leftarrow} - i\partial_t^{\rightarrow})\psi\sqrt{g_2}d^2x - N(\#)\right] \;. \tag{21}$$

   The term breaks manifest coordinate invariance.

3. At least in the length scales sufficiently larger than molecular length scales, the volume of the 3-surface can be assumed to be fixed since hydrodynamic flow is incompressible in excellent approximation. This amounts to the addition of a Lagrange multiplier term

$$S_2 \;=\; \int dt\lambda_2(t)\left[\int \sqrt{g_3}d^3x - V\right] \;. \tag{22}$$

This term gives rise to a term appearing as a source term in the equations determining the geometric form of the boundary of the 3-surface.

4. The intuitive expectation # contact BE condensate can exist in two phases analogous to super conductor of type I and II respectively. In the first phase the surface area is minimized and the density of the # contacts is maximized. This phases clearly corresponds to the situation in which the 3-surface is far from a vacuum extremal. In the second phase the surface area is maximized and the density of the # contacts is minimized. This phase corresponds to the 3-surface near to a vacuum extremal and the generation of regions of this phase can lead to the changes of the molecular conformations and to the changes of the macroscopic shape of the organ. The presence of the two phases is achieved by adding a "mass renormalization term"

$$\begin{aligned} L_\Delta &= \Delta m^2 n\sqrt{g} \ , \\ n &\equiv \bar{\psi}\psi \ . \end{aligned} \tag{23}$$

to the action and taking care that the # contacts propagate with a correct mass by using a Lagrange multiplier:

$$L_3 = \lambda_3 L_0 \ . \tag{24}$$

Δm^2 could also have a slow dependence on position.

5. The sign of Δm^2 determines the character of the system. If the sign is postive/negative the surface energy density is negative and surface area is minimized/maximized. Thus Δm^2 could serve as a control parameter, whose changes induce changes in the conformation of the 3-surface. The value of Δm^2 could be taken as input and could depend on parameter such as temperature and electromagnetic potential differences. One can imagine the existence of a critical temperature T_c such that $\Delta m^2 \propto T_c - T$ holds true. In low temperatures the 3-surface would freeze and minimizes the area of its outer boundary. In high temperatures 3-surface would become fractal like and random.

6. The maximization of the surface area with a fixed volume leads to an in-stability since a surface with a given volume can have an arbitrarily large surface area. This suggests that Δm^2 term contains also a regulating term nonlinear in ψ. In the spirit of Ginzburg-Landau action, one could have

$$\begin{aligned} L_{\Delta_1} &= \Delta_1 m^2 n\sqrt{g} \ , \\ \Delta_1 m^2 &= \lambda(n - n_0) \ , \\ n &\equiv \bar{\psi}\psi \ . \end{aligned} \tag{25}$$

The most reasonable choice for the sign of the term is dictated by the stability requirement. Below the critical value n_0 of the # contact density the 3-surface should be minimized (, which increases n) its area whereas above n_0 the area should be maximized (, which reduces n). This term need not appear in the wave equation as usually, if the constraint term gives wave equation. It however appears in the energy density and the ground state solution can be fixed by requiring the minimization of the energy.

4.5.2 Field equations

With these assumptions the field equations reduce to the wave equation for the order parameter in the induced metric

$$(-D^\mu D_\mu - m^2)\psi \;=\; 0 \;, \tag{26}$$

and to equations analogous to the conservation of the energy momentum associated with the order parameter:

$$\begin{aligned} D_\beta(T^{\alpha\beta}\partial_\beta h^k) &= \lambda_1 g_3^{n\beta}\partial_\beta h^k + ... \;, \\ T_{\alpha\beta} &= \bar{\psi} D_\alpha^{\leftarrow} D_\beta \psi - \frac{1}{4} g_{\alpha\beta} L_0 \;. \end{aligned} \tag{27}$$

The source term comes from the volume constraint. There are analogous source terms associated with the other constraints. These terms are present only provided the corresponding Lagrange multipliers are non-vanishing.

Neglecting the presence of the gauge potential terms, possibly not transformable away by a gauge transformation, the simplest stationary solution of the equations is of the form

$$\begin{aligned} \psi &= exp(imt)\psi_0 \;, \\ n = \bar{\psi}_0\psi_0 &= \frac{N(\#)}{mA} \;, \end{aligned} \tag{28}$$

where A is the total surface area. The terms involving time derivatives disappear from the field equations determining the 3-surface and if Δm^2 is non-vanishing the field equations reduce to the condition stating that the 3-surface minimizes/maximizes its surface area subject to the condition that its volume is fixed. In the critical case with $\Delta m^2 = 0$ the equations state nothing about the form of the boundary surface and it becomes completely random (but static) at criticality.

4.6 Model for weakly coupled wormhole super conductors

Wormhole super conductivity played a key role in earlier quantum model for EEG and nerve pulse. Although it turned out that the proposed role is very probably not realized in real world, weakly coupled wormhole super conductors are quite possible and there is even evidence for them. The hypothesis that potential differences associated with various Josephson junctions correspond to cyclotron frequencies, suggests that cell interior and exterior should form pair of weakly coupled wormhole super conductors such that the wormholes contacts in question connect $k = 169$ cellular space-time sheet and $k = 173$ space-time sheet at the next level of the hierarchy. The time scale associated with this particular wormhole super conductivity is obviously quite different from that associated with nerve pulse generation and EEG and the time scale in which possible quantum control takes corresponds to the natural time scale for molecular vibrational levels (photon energies in near infrared). In the following model for the Josephson junction of wormhole super conductors assumes for definiteness that lipid layers of the cell membrane are the coupled super conductors: reader can easily generalize the results to more general case.

4.6.1 Physical picture

The effective charge carriers are # contacts feeding em charge between two space-time sheets. There are actually opposite classical em currents at the two space-time sheets and in quantum field

context there is just the current of extremely tiny Planck length scale dipoles having practically no coupling to photons (this makes dissipative effects very small!). # contacts couple to the difference ΔA of the classical gauge potentials and of the order parameters describing topologically condensed coherent photons associated with the two space-time sheets joined by the # contacts. This provides the needed coupling to the classical fields and to the coherent photons generated by micro-tubuli serving as quantum antennas. # contact BE condensate couples also to the geometry of the boundary of the 3-surface since the action defining the dynamics contains the induced metric of the boundary regarded as a dynamical variable. In the present context this coupling is not important.

The complex order parameter for # contacts satisfies d'Alembert type wave equation with minimal coupling to ΔA. The order of magnitude for the lowest excitation energies is $\Delta E \sim 1/L$, where L is the size of the join along boundaries condensate to which the # contacts are associated. The mass of # contact is from p-adic length scale hypothesis inversely proportional to the p-adic length scale $L(p)$ associated with the larger space-time sheet: $m \sim 1/L(p)$. For instance, for cell membrane the relevant p-adic length scale is roughly the thickness $L(p) \sim d \sim 10^{-8}$ meters of the cell membrane and one has $m(\#) \sim 10^2$ eV. Because of their small mass # contacts form a BE condensate, when temperature is below $T \sim 1/L$ (this estimate is probably too conservative): in the room temperature the largest size of join along boundaries condensate would be thus of order 10^{-4} meters, which is indeed the size of largest known information processing structures in cortex [I3]. It must be emphasized that thermal argument is probably conservative: large space-time sheets need not be in thermal equilibrium with atomic space-time sheet and in fact they are *not* in the TGD based realization of living matter as a hierarchy of weakly coupled super conductors. By their extremely small coupling to photons # contacts (photonic dissipation is minimal) might be able to form BE condensates even above $T \sim 1/L$. As far as mathematical description is considered, charged # contacts behave very much like Cooper pairs. In particular, the concept of Josephson junction generalizes.

For # contacts "Josephson junctions" are join along boundaries bonds connecting the lipid layers together on the smaller space-time sheet, the larger space-time sheet is a connected surface. These bonds could correspond to weak chemical bonds between the hydrophobic ends of the lipids and need not be stable. Also the proteins connecting lipid layers could serve as Josephson junctions. Josephson junctions are idealized with a continuous distribution so that one can imagine a continuous sheet of thickness $d \sim 10^{-9} - 10^{-10}$ meters between the lipid layers serving as a single Josephson junction. Join along boundaries contacts make possible the motion of the # contacts between the join along boundaries condensates associated with the lipid layers. This induces a coupling between the order parameters associated with the two lipid layers. One obtains Sine-Gordon equation coupled to gauge potential by generalizing the argument of Josephson from Schrödinger equation to almost massless d'Alembert type wave equation for the order parameter describing the BE condensates of # contacts at the boundaries of the two join along boundaries condensates. Sine-Gordon coupled to a gauge potential difference is obtained directly whereas for the Cooper pairs Sine-Gordon is obtained from the Maxwell equation $\nabla \times B = J$ by assuming that order parameter satisfies covariant constancy conditions, which in turn forces to make ad hoc assumptions and would lead in the recent case to difficulties.

4.6.2 Field equation for the phase difference

The basic assumptions of # contact models are following. For definiteness only axon (of radius R, typically of order $R \sim 10^{-6}$ meters) is considered. Lipid layers are regarded as cylindrical surface of thickness d of order $d \sim .5 \times 10^{-8}$ meters. The distribution of the join along boundaries contacts serving as Josephson junctions is replaced with a continuous density of the join along boundaries contacts of thickness of order $10^{-9} - 10^{-10}$ meters. The order parameter is assumed to have approximately constant modulus

$$\bar{\Psi}\Psi \approx constant \ . \tag{29}$$

This requires that # contact flow between the lipid layers induces only small fractional changes in the total charge. The phase of the order parameter is assumed to depend on the time coordinate t and the longitudinal coordinate z of axon only.

The order parameter is assumed to satisfy linear d'Alembert type equation derivable from an action containing no higher nonlinearities than quadratic mass terms. General Ginzburg-Landau type action for the order parameter allows also quartic nonlinearities. These couplings are indeed needed to guarantee the stability of the system but are not relevant for the recent discussion. The action contains also a coupling to the geometry of the boundary regarded as dynamical. The coupling is via the induced metric and the corresponding field equations are analogous to the conservation laws for energy momentum. Also this aspect is irrelevant for the recent purposes although it might be important for the understanding of the geometrodynamics of the cell membrane during the nerve pulse propagation (the opening/closing of various ion gates corresponds to a change of the topology for the cell membrane 3-surface).

Consider now the derivation of Sine-Gordon type equation for the phase difference associated with # contact condensates. The difference with respect to the standard derivation is that # contacts satisfy − not Schrödinger equation − but d'Alembert equation with very small mass and couple to the difference of gauge potentials associated with larger and smaller space-time sheet. Of course, nothing hinders using relativistic formulation also in case of ordinary super-conductors.

The coupling between the order parameters associated with the boundaries of two lipid layers is represented by a non-diagonal mass squared term $J_1 = \frac{1}{\Lambda^2}\Psi_2$, $J_2 = \frac{1}{\Lambda^2}\Psi_1$. Taking $x^0 = vt$ as time coordinate the equations read

$$\begin{aligned}
(D + m^2)\Psi_1 &= J_1 = -\frac{1}{2\Lambda^2}\Psi_2 \ , \\
(D + m^2)\Psi_2 &= J_2 = -\frac{1}{2\Lambda^2}\Psi_1 \ , \\
D &= D_\mu D^\mu = D_0^2 - \sum_i D_i D_i \\
D_\mu &= \partial_\mu + iQ\Delta A_\mu \ .
\end{aligned} \tag{30}$$

Q denotes the charge of # contact: if # contact is created, when electron is dropped from the atomic space-time sheet on the larger space-time sheet then its charge is positive: $Q = e$. Note that field equation of the same general form can be derived for weakly coupled super conductors quite generally.

If the fractional changes of the charge densities caused by Josephson current are small, the assumption that the moduli of Ψ_i are equal to same constant is a good approximation. Thus the ansatz is of the following general form

$$\begin{aligned}
\Psi_i &= R_i exp(i\omega t + \Phi_i) \ , \quad i = 1, 2 \ ; \\
\omega &= mv
\end{aligned} \tag{31}$$

where $R_i = R$ is constant in the approximation used and v is the possibly reduced light velocity. By taking the difference for the imaginary parts of the field equations one obtains the following equation

$$D^\mu(\partial_\mu\Phi + Q\Delta A_\mu) = -\frac{1}{\Lambda^2} sin(\Phi) \ . \tag{32}$$

for the difference $\Phi = \Phi_2 - \Phi_1$ of the phases of the order parameters Ψ_1 and Ψ_2. This equation is 1+2-dimensional Sine-Gordon equation coupled to the gauge potential difference and reduces to Sine-Gordon if ΔA is small compared with the gradient of Φ. This is assumed to hold true in the sequel. It must be however emphasized that this coupling provides an important back-coupling term in the interaction between ordinary matter/coherent photons and the BE condensate of # contacts.

In cylindrical geometry the solutions can be assumed to be independent of the angle coordinate and one has 1+1-dimensional Sine-Gordon equation

$$\begin{aligned} (-\partial_0^2 + \partial_z^2)\Phi &= \frac{1}{\Lambda^2} sin(\Phi) \ , \\ x^0 &= vt \ , \end{aligned} \tag{33}$$

known to be a completely integrable system[21].

5 TGD and biochemistry

TGD brings in several new elements at the level of biochemistry.

1. Macro-temporal quantum coherence due to the spin glass degeneracy.

2. The geometric form of the bio-molecules ceases to be a phenomenological concept in TGD approach.

3. Chemical bond can be identified as the join along boundaries bond between two 3-surfaces.

4. # contacts might be the crucial step from the ordinary organic chemistry to biochemistry. For # contact super conductivity the conditions are rather mild since in TGD context the presence of light # contacts and thus their BE condensates is almost unavoidable. The hypothesis that some organic molecules might behave as # contact super conductors suggests a completely new manner to understand the bio-control at the level of DNA and proteins.

5. Almost vacuum space-time sheets carrying non-vanishing vacuum currents are possible in TGD and these currents generate coherent states of photons. The topologically condensed coherent photons can couple to the # contact BE condensates. Comorosan effect [48, 49] is a good example of a phenomenon having an explanation in terms of a molecular # contact BE condensate coupling to coherent photons [J5].

6. Nuclei can be regarded as completely ionized Z^0 ions and generate classical Z^0 fields screened by neutrinos. Z^0 fields seem to be fundamental for the understanding of the condensed matter stability and also the stability of molecules. The quantum control of the density of cellular water could explain the extreme effectiveness and sensitivity of catalysts. The axial part of classical Z^0 field can in turn explain the chirality selection of organic molecules in vivo. The central role of Z^0 force in biochemistry and pre-biotic evolution has become obvious only gradually and will be discussed in a separate section.

5.1 Macro-temporal quantum coherence and molecular sex

The formation of bound states is a generic mechanism for generating new quantum fluctuating degrees of freedom and could make possible quantum computation like processes and multiverse states of consciousness containing large amounts of conscious information. At macrolevel sexual organism could be basic example of multiverse state of oneness generated by the formation of

quantum bound state between partners. Neuroscientists use to talk about rewards and punishments and one might argue that life involves kind of sexual pleasure as a reward for the formation of bound states at all levels of hierarchy. Spiritual experiences would represent a more abstract experiences of this kind involving the formation of bound states of the field bodies by MEs serving as field bridges.

Some examples are in order.

1. The binding of molecules by lock and key mechanism is a fundamental process in living matter and could generate large number of quantum fluctuating degrees of freedom and generate conscious intelligence. This could explain why long linear macromolecules are so important for life. From the viewpoint of classical chemistry it is not obvious why DNA is arranged into long chromosomes rather than separate short threads. In TGD universe the reason why would be that for chromosomes the number of quantum fluctuating degrees of freedom and thus the amount of conscious intelligence is maximized.

2. The Ca^{++} ions binding to micro-tubuli and molecules like calmodulin could act as switch like bridges between water clusters and micro-tubuli and thus able to dramatically increase the number of quantum fluctuating degrees of freedom and initiate quantum computation like process. The de-attachment of Ca^{++} ions would halt the process.

3. The binding of the information molecules to receptors is a universal control mechanism in living matter. In TGD universe information molecule would initiate genuine quantum information processing lasting for the lifetime of the information molecule-receptor complex. In particular, neurotransmitters could induce molecular states of oneness in receptor-neurotransmitter complex or perhaps even in larger-sized structures. If neurotransmitters have join along boundaries bonds to other neurons mediated by magnetic flux tube structures, they could act as conscious quantum links in quantum web and induce quantum computation like processes involving distant neurons just as link links in the web induce classical computations involving distance computers.

4. One could see information molecules and receptors as representatives of opposite sexes: information molecules being active quantum binders free to move from flower to flower whereas receptors would be the passive party attached to some structure. The binding of the information molecule to the receptor would be the analog of sexual intercourse. Usually the receptors are bound to larger structures such as cell membrane and also the zero modes for some parts of these larger structures could become quantum fluctuating in the process.

5.2 Organic polymers as topological field quanta

Organic polymers, in particular proteins formed as sequences of 20 different amino acids and DNA and related molecules formed as sequences of 4 basic nucleic acids, are the basic molecules of living matter and their characteristic features are their effective one-dimensionality and richness of structures. For example, proteins and nucleic acids can have several conformations: they can behave like aperiodic crystals or as random coils. Muscle proteins in turn can change their length in the contraction of the muscle. The conformation of the polymers is known to be sensitive to its electronic structure and to the properties (in particular pH) of the ionic environment. The chemical properties of silicon are very similar to those of carbon but for some reason(s) only carbon based life has developed.

A good TGD based model for organic polymers is as topological field quantum with approximate cylindrical symmetry. Linear structures are indeed in a very special position in TGD since the imbedding of the Kähler electric field associated with the field quantum gives no constraints on the length of the field quantum.

5.3 Organic molecules as super-conductors

The basic organic molecules appearing in regulative tasks (co-enzymes, vitamines, hormones) contain closed rings for which electron pairs are known to be delocalized along the ring, so that they could form super conductor. Also the basic building blocks of DNA contain closed rings although conjugated π bonds are absent [32]. It is quite possible that the vacuum quantum number n_i associated with these loops are non-vanishing and therefore carriers of a biological information. Electronic super conductivity is not the only possibility: also # contacts could form supra currents flowing in these loops.

The changes in the vacuum quantum numbers associated with the closed loops of the organic polymer are generated by a phase slippage [28]. Phase slippage generates a localized kink, which corresponds to a supra current analogous to a nerve pulse. An interesting possibility is that these kinks might control biochemical reactions.

5.3.1 Possible applications

One can imagine several applications for these excitations in the bio-control.

1. For the biochemical reaction to proceed it is necessary to have free energy, which enables to overcome activation energy barriers. This energy should be stored to the structure of the catalysts and possibly also of substrate in some form [32]. According to [32] the storage mechanism is not established yet. What certainly happens is that free energy liberated, when catalyst and substrate join together, must go to some degrees of freedom. One suggestion is that the vibrations of the compound molecule serve as a storage of free energy [32]. The first TGD inspired alternative is that the free energy liberated in the joining of catalyst and substrate is stored to the kinetic energy of the supra charge carries rotating along the loops of the compound molecule (quantum number n_i) and can be used as an activation energy storage helping to overcome the activation energy barriers. As already noticed, the energy liberated form ATP is of the same order as the kinetic energy associated with a rotating charge carrier. A more radical TGD based alternative is that the loops of the organic molecules in vivo contain additional negentropy in the form of the slowly dissipating supra currents.

2. Josephson junctions between two super-conducting organic molecules (say the two strands of DNA) are possible [28] are possible. Hydrogen bonds are good candidates for these Josephson junctions. An oscillating Josephson current flows in the junction [28]. In presence of several junctions destructive interference can take place between the currents provided there are phase differences between various junctions if there are supra currents flowing in the rings of the two molecules joined together by several hydrogen bonds (say DNA double helix). The composite structure (say DNA double helix) is expected to become unstable if too large total Josephson current runs through the junctions. Therefore the supra currents can act as a stabilizing mechanism for the composite molecule and the decay of the molecule takes place, when supra current dissipates by phase slippages.

5.3.2 Why # contacts/Cooper pairs are ideal tools of bio-control

There are several good reasons for why # contacts/Cooper pairs could provide a tool of bio-control.

1. # contacts/Cooper pairs are in the same quantum state and therefore they serve as a source of negentropy and one can consider the possibility that the BE condensate of the charge carriers is actually the carrier of the most relevant bio-information. In case of the enzymes this negentropy would provide a source of free energy needed to overcome activation energy barriers in the catalysis of the various chemical reactions. The dissipation associated with

the motion of the charge carriers resulting from the phase slippage mechanism is very small. Phase slippage in n_i takes typically by the splitting and rejoining of a join along boundaries bond. A measure for the rate of dissipation is the frequency for the splitting of the bond. The larger the bonding energy of the chemical bond, the smaller the rate of splitting is expected to be.

2. The complex order parameter describing the quantum state can be assumed to be covariantly constant in the ground state since the induced gauge fields are expected to vanish on the boundaries of the 3-surface. For Cooper pairs in the interior of 3-surface this assumption is probably also a reasonable approximation. As can be found in [D7], some information about the homotopy of the 3-surface is directly coded into the phase of the ground state order parameter for supra phases and same holds true for # contacts, which couple to the difference of the gauge potentials associated with the two space-time sheets. Since the creation and destruction of the join along boundaries bonds changes the homotopy of 3-surface and since join along boundaries bonds are crucial for the properties of the macroscopic quantum system, this phase information is expected to be also biologically relevant. The spatial constancy of the density of # contacts /Cooper pair implies that the effects caused by the # contact/Cooper pair density are global so that the changes in the density produce co-operative effects.

3. In TGD the "act of free will", which is the most characteristic feature of bio-system, corresponds to a quantum jump between quantum histories. The quantum jumps induced change in the properties of the effective space-time and the BE condensate associated with it and the relevant aspects of the change could therefore correspond to the change of the order parameters describing # contacts/Cooper pairs and coherent states of photons.

4. The conformations of the organic molecule are expected to be sensitive to the distribution of the # contacts/Cooper pairs. The creation of an in-stability leading to a new conformation would correspond to the generation of a region of a molecular 3-surface, which is a mall deformations of a vacuum extremal of the Kähler action. For instance, this kind of redistribution might lead easily to the destruction or creation of the join along boundaries contacts. The same of course applies to the Cooper pairs and it is known that the conformations are sensitive to the electronic configuration. It could however be that the electronic configurations are not the fundamental controllers but are controlled by the configurations of # contacts behaving as classical charges.

5. By their lightness (having inertial mass of order $1/L(n)$ on dimensional grounds), # contacts provide a rapid mechanism for control and the classical field energy needed to accelerate # contacts is small (recall that # contacts couple to the *difference* of the gauge potentials associated with the two space-time sheets. The dissipation effects (not desirable in control and coordination signals) are extremely small since the coupling to ordinary photons (as opposed to topologically condensed coherent light) is extremely small dipole coupling (dipole with size of CP_2 radius is in question!). Also Cooper pairs are light and therefore very mobile and the kinetic energy associated with their motion (supra currents along closed loops and kinks) is very small and quantized, so that the density of the Cooper pairs could serve as an ideal control switch. For example, the kink of width L possesses momentum of order $p \simeq 2\pi/L$ ($\bar{p} = \nabla\Phi$ for Cooper pairs), so that its energy is $E = \pi^2/m_e L^2$, which is in general smaller than the delocalization energy.

6. The importance of the aqueous environment (with $pH \simeq 7$) for organic molecules might be related to the partial ionization of water in the following manner. There are two kinds of effects. The appearance of protons (about 1 per $10^{-25}m^3$) is expected to in-stabilize

the polymer since it creates classical gauge fields interacting with # contacts/Cooper pairs leading to the generation of density gradients. On the other hand, the presence of the hydrogen bonded polymers of the water molecules has a stabilizing effect since the join along boundaries bond between an organic molecule and structure of this kind increases the delocalization volume for the charge carriers.

5.3.3 # contacts or Cooper pairs of both?

contact super conductivity at all levels of the # condensate, in particular in the case of organic molecules, seems almost unavoidable. A possible explanation for why it is not observed is the extremely weak interaction of the # contacts with ordinary photons and the interaction with laser light provides a test for the idea. The Comorosan effect involving the interaction of the laser light with organic molecules could in fact be regarded as a positive evidence for the concept.

In case of electrons, super conductivity is not at all obvious and the standard wisdom about macroscopic super conductors excludes this possibility. In TGD context, the dropping of electrons on larger space-time sheets could make it possible to have also electronic super conductivity. The interaction between electrons induced from the interaction of the electrons with the # contacts creating the excitations of # contact BE condensate, could give rise to the formation of the Cooper pairs.

Join along boundaries bond makes possible the delocalization of the valence electrons. The pairing of the valence electrons to the spin singlet states occurs invariably in this process. Valence electrons can delocalize to a volume of two neighboring atoms as in covalent bond or to a volume of several atoms as in case of the benzene ring. Hydrogen bond is related to the delocalization of the electrons in the saturated valence bonds, for example water molecules join together by a hydrogen bond. The hydrogen bond can be interpreted as a delocalization of the valence electron pairs to a volume of several molecules. In case of the ionic bond, the exchange of electrons between atoms takes place, so that atoms are ionized and an increase of the Coulombic binding energy is achieved.

If the delocalization of the electrons is complete, organic molecule becomes conductor. Even more, if the electrons are paired to spin singlet states a transition to super conducting phase might take place: in this manner it might be possible to minimize the increase of the electron kinetic energy implied by the Pauli Exclusion Principle. A possible mechanism of delocalization is the dropping of some electrons on larger space-time sheets from the atomic space-time sheets. In these sheets the density of charge is small and the interaction with # contacts could give rise to the formation of the Cooper pairs. An additional condition must be however met: the gap energy of electronic super conductor is extremely small unless the super conductor is effectively one-dimensional. The presence of weak magnetic fields guarantees this. Since the temperature at non-atomic space-time sheets can be extremely low, very weak magnetic fields are enough to achieve this.

The necessary condition for the appearance of super conductivity is that the delocalization energy of the electron given by the expression $E_{deloc} \simeq \frac{1}{2m_e\xi^2}$ is larger than the thermal energy and implies that critical temperature is of the order of $T_c \simeq 5\ eV = 0.5 \cdot 10^5\ K$, so that super conductivity is in principle possible in the biosphere.

The obvious counter argument against electronic super conductivity, is that in thermodynamic equilibrium the quantum numbers n_i vanish with a very high probability: the exponent $exp(-E/T)$ is extremely small. The point is however that living matter is not in thermodynamical equilibrium but rather an open system, to which entanglement entropy (rather than negentropy!) is fed continually. The entanglement entropy might be stored at molecular level to the supra currents and due to the small dissipation rate of supra currents these states are so long lived that thermodynamic equilibrium has not enough time to set up. The supra currents in turn might be created at the

moment of the formation of the bio-molecule and guarantee the stability of the molecule. Later a model of DNA based on the idea that the closed rings associated with the basic units of DNA in vivo carry non-vanishing quantum numbers n_i DNA and guarantee the stability of double DNA helix, will be considered. If # contacts are the carriers of the supra current then the interaction with the ordinary, in particular thermal, photons is effectively absent and the thermodynamical argument does not apply. # contacts however couple to the topologically condensed coherent photons and this coupling might be crucial for the functioning of the bio-system. The TGD based explanation of the Comorosan effect [J5] is based on the assumption that this coupling exists.

5.3.4 Candidates for super-conducting organic molecules

Promising candidates for super conducting organic molecules are the compounds containing cyclic structures since the delocalization of the electron pairs is known to occur for certain hydrocarbon rings through the formation of the so called conjugated π bonds [32]: benzene is a classic example of this phenomenon. In this case electronic super currents would correspond to $n_1 \neq 0$ excitations of the electron pairs with kinetic energy of order $n_1^2\pi^2/4m_eL^2$, where L is the radius of the loop in question: energies are of the order of few electron volts. For # contacts the energy is of order $\pi/L(n)$, where $L(n)$ is the relevant (actually p-adic) length scale.

Very many important organic monomers possess carbon rings of this type and the rings are good candidates also for the carriers of # contact supra currents.

1. The compounds AMP, ATP and ADP, which serve the role of energy batteries contains rings of this type. Also coenzymes, vitamines and hormones having central role in biological control contain rings of this type. One might well imagine that super conductivity appears in the single ring, so that non-vanishing supra currents correspond to non-vanishing quantum numbers n_1 associated with these rings. The excitation energies ($E = n_1^2\pi^2/m_eL^2$ for a loop of size $L \simeq 10^{-9}$ meters are typically of the order of electron volt).

2. Amino-acids, which serve as the basic building blocks of the proteins, do not contain any closed rings but the biologically active α helix form of the protein contains hydrogen bonds between the NH and CO groups and these bonds might might make # contact/ordinary super conductivity possible. In biologically nonactive random coil form these bonds are absent [32]. This suggests that the presence of the supra phase indeed is what makes dead matter living.

3. Nucleic acids, the building blocks if DNA and related molecules, contain nitrogenous bases, which are rings but do not contain conjugated π bonds, so that it is not clear whether supra current are possible in this case. There are however indications that DNA is a source of the visible light [53, 54]. A possible TGD based explanation for this effect is as light emitted in the delocalization of the Cooper pairs. Biologically active helix form of DNA is also optically active unlike the random coil form [32].

4. For the electronic super conductivity, the gap energy for $L \sim 10^{-8}$ meters corresponds to the energy of the photon of the visible light, so that visible light is expected to be a particularly effective localizer of a Cooper pair. An interesting question is whether this sensitivity might provide additional insight to the understanding of photo-biochemical reactions, in particular photosynthesis, and the mechanism of the vision. In fact, the decay of an electron pair to unpaired electrons is known to take place, when clorophyll molecule absorbs photon [32], which suggests that photon energy goes directly to the delocalization of the Cooper pairs. The hypothesis explains also why vision is sensitive to visible light only. Also the excitation of the # contacts from ground states on the boundaries of a surface having size of order cell size would involve photon absorption.

5.4 Bio-catalysis and TGD

The main function of the proteins (sequences of amino-acids) is to serve as catalysts for various biochemical reactions. The characteristic feature of the biochemical reactions is extreme selectivity, which necessitates an effective recognition mechanism between bio-molecules.

The simplest model for the catalytic action is the lock and key mechanism. The catalyst and substrate fit together like lock and key. This kind of a mechanism is indeed very natural in TGD inspired picture and corresponds to a partial join along boundaries. The lock and key mechanism fails to describe all features of the bio-catalysis: the conformations of the bio-molecules are known to be dynamic rather than static and sensitive to the electronic configuration. A refined version of the lock and key mechanism is the so called induced fit [32]. The structures of the substrate and catalyst are not assumed to be static anymore. When substrate and catalyst have joined together they can change their conformational structures before the reaction takes place. TGD indeed predicts that the conformation of the resulting state is in general unstable. After the join along boundaries reaction however, a redistribution of # contacts/Cooper pairs in the whole reaction volume takes place and the conformation changes until a minimum of E is found.

By the previous considerations # contact BE condensates associated with the organic molecules could play important role on the catalytic mechanism. What happens in the Comorosan effect is that the stimulation of the organic molecules with laser light lasting a multiple of basic period $\tau \sim 5$ seconds enhances the catalytic activity. The TGD based explanation of the Comorosan effect [J5] relies heavily on the assumption that the Josephson junctions formed between enzyme and substrate molecules affects the rate of the reaction and also explains all the mysterious looking regularities of with the effect [48, 49].

5.5 TGD inspired model for the unwinding and replication of DNA

As an example consider a TGD inspired model for the unwinding and replication of DNA molecule. The unwinding is known to proceed either spontaneously or with the help of DNA polymerase during replication [32]. It has turned out to be difficult to understand the mechanism behind the spontaneous unwinding of the double helix [32]. The replication takes place in the following steps. The presence of the DNA polymeraze attached along the double helix causes the unwinding of the double helix by setting the strands in a rotational motion in the same direction and by splitting the hydrogen bonds between the nitrogenous basis of the composite strands. The hydrogen bonds are formed between the cyclic nitrogenous bases A(denine), C(ytocin), G(uanine) and T(hymine) and only A-T and C-G bonds are possible.

The difficulties are related to the understanding how the unwinding can take place so rapidly [32]. The simplest mechanism explaining the unwinding is based on the assumption that DNA molecule rotates very rapidly along its axis at the beginning of the unwinding process. If one fixes the second end of the double strand then unwinding takes place automatically and the angular frequency for the unwinding is essentially equal to the rotation frequency. The estimate for the angular frequency of the rotation is however very large even for the shortest DNA molecules (having length of about 10^{-8} meters): rotation frequency is about 10^4 times per minute! This doesn't look sensible since dissipation should destroy the rotation of DNA rapidly. In fact this rotation rate corresponds to an angular momentum of few Planck units and this suggests that quantum effects are involved.

5.5.1 First model

The simplest TGD based model for the unwinding is based on the following assumptions. The model is formulated assuming that # contacts are the carriers of the supra current but it applies also in case of the Cooper pairs.

1. There is a condensate of # contacts along the whole DNA molecule. # contact supra current flows in the loops of DNA strands in same direction, so that there is a net angular momentum associated DNA molecule. The integers n_i associated with all loops along DNA molecule are identical by the complete delocalization of the charge carriers. Since supra phase is in question the dissipation rate for this angular momentum is low unlike for the ordinary rotational angular momentum of the double strand.

2. There are two mechanisms leading to the unwinding of the DNA molecule.
   i) The destruction of some # contacts takes place so that the angular momentum of these pairs is transformed to the rotational angular momentum of the DNA molecule itself. The disappearance of the # contacts involves the transfer of charge between space-time sheets and might well involve a transfer of electrons from the "larger" space-time sheet to the atomic space-time sheet. Hence also the disappearance of the Cooper pairs from the larger space-time sheet (if present there) might be involved.
   ii) Phase slippage takes place along the whole DNA molecule, so that the integers n_i characterizing the behavior of the order parameter change in all loops along DNA and the angular momentum is liberated to a coherent rotational motion of the whole DNA molecule. The phase slippage liberates angular momentum of order $J = N_c\Delta n_1$, where N_c is the number of the # contacts in the molecule. For the shortest DNA molecules N_c should be about one. In general, the linear density of the # contacts should be about one pair per 10^{-8} meters.

3. If the second end of DNA molecule is fixed, DNA molecule unwinds. Otherwise the angular momentum of the DNA molecule is gradually dissipated.

5.5.2 Second model

The splitting of the double strand into single strands might be caused by the mere unwinding. It is also possible that the Josephson currents of # contacts are involved in the process. A more refined TGD inspired scenario for the unwinding and replication of DNA looks like follows.

1. The cyclic rings associated with the complementary bases are carriers of # contact supra currents. The hydrogen bonds between the rings (2 or 3 depending on situation) can be regarded as Josephson junctions. Therefore an oscillatory Josephson current flows between the complementary basis in the double helix of DNA. If the supra currents in the basis loops rotate in the same direction, the phase differences between the hydrogen bonds are maximal and a destructive interference between Josephson currents occurs and guarantees the stability of the double helix. Since the currents rotate in the same direction there is a net angular momentum associated with these supra currents.

2. The dissipation caused by the phase slippages implies that this supra current becomes small in the course of time. This can take place in several steps or in single step depending on the value of n_1. This effect is collective and take place for all loops of the DNA molecule propagating in a wave like manner from one end of the molecule to the second end. If the second end of the DNA molecule is fixed, this process leads to the unwinding of the DNA molecule.

3. When the critical phase slippage occurs, Josephson current achieves the critical value making the double helix structure unstable, so that the hydrogen bonds break and this leads to the splitting of the double strand.

4. The role of the DNA polymeraze in DNA replication is to keep the second end of DNA fixed and possibly to generate the supra current kink, which interferes destructively with the super current in loops and leads to the amplification of the Josephson current.

5. The replication of the resulting strands is achieved by introducing the complementary nucleotides. The formation of the double DNA strand can be regarded as a time reversal of the unwinding of the double DNA. In this case catalyst must take care that correct pairs are glued together by the hydrogen bonds. The formation of the stable hydrogen bonds is possible only provided non-vanishing supra currents are generated in the loops associated with the complementary nitrogenous bases. Angular momentum conservation implies that the strands get into a winding motion provided the direction of the supra currents is correct. DNA double helix is formed.

6. The process doesn't lead to the unwinding of DNA unless the second end of DNA is fixed. In case that no unwinding occurs, there must exist some mechanism regenerating the original supra current in the DNA molecule since otherwise DNA molecule would gradually lose its angular momentum and its ability to unwind and replicate. In fact, the presence of the supra current might be essential for the stability of DNA and the rejoining of the hydrogen bonds after the phase slippage might automatically generate the needed supra current. In this process a feed of negentropy from the environment to DNA molecule obviously takes place.

6 TGD and morphogenesis

Morphogenesis, that this the formation of the spatial bio-structures during the development, is one of the not so well understood biological phenomena [19]. There are several problems related to this phenomenon.

1. What dictates the size and the form of the bio-structures?

2. What are the basic control mechanisms altering the size of the existing structures, say, the length of the muscle?

3. What are the mechanisms controlling morphogenesis? What is the clock, or rather the alarm clock, taking care that the division of a cell or the formation of an organ during the morphogenesis begins at certain time? How is the information about the formation of the spatial structures contained in the developing embryo? How is the spatial ordering and synchronization of several parallel processes achieved?

In the sequel the generation of both spatial and temporal structures is considered and an actual realization for biological clocks and biological alarm clocks as supra current circuits by generalizing the ideas of the TGD based model of nerve pulse and EEG, is proposed. The role of genome in the control of the morphogenesis will be considered only very briefly and the ideas related to many-sheeted DNA are left to a separate chapter [L2].

6.1 Topological field quantization and vacuum quantum numbers

Topological field quantization provides a TGD based first principle explanation for the existence of the spatial structures. The size of the bio-structure depends on the vacuum quantum numbers and is dictated by the stability criterion (the sum of Z^0 Coulombic energy and electronic delocalization energy is minimized). The hypothesis that bio-systems are super conductors at the first level of the condensation implies that supra currents are a basic tool of the bio-control. The density of the charge carriers dictates the stable size and form of the organ and also the nontrivial phase information carried by the order parameter is expected to be important.

There are handful of vacuum quantum numbers arising from the time and spatial behavior of the phase angles ϕ_i associated with the two complex CP_2 coordinates [D7]. One can express

the dependence of these phase angles on space-time coordinates as a sum of Fourier expansion plus zero mode term linear in some coordinates and not allowing Fourier expansion. In linear Minkowski coordinates the vacuum quantum numbers would define components of four-momentum. In spherical coordinates vacuum quantum numbers correspond to frequency, momentum in given direction plus integer analogous to the component of the angular momentum in the direction of momentum. The set of vacuum quantum numbers associated with the two phase factors depends on the choice of the coordinates for M^4_+ and CP_2 and involves a selection of maximal number of mutually commuting observables in the Lie-algebras of Poincare group and color group. This is consistent with the fact that topological field quantization indeed is the classical counterpart of quantization. The construction of quantum TGD and understanding of the p-adic aspects of quantum TGD involves in an absolutely essential manner the choice of these quantization axes.

To fix the notation, the quantum numbers associated with the spherical coordinates will be denoted by (ω_i, k_i, n_i), $i = 1, 2$. detailed definitions of vacuum quantum numbers reader should consult the appendix of this book and [D7]. The first consequence is that given space-time sheet is characterized by two frequencies. A good working hypothesis is that the frequency difference associated with two space-time sheets connected by Josephson junctions corresponds directly to the voltage difference over Josephson junction: $\Delta\omega_1 = ZeV$. Besides the group theoretical quantum numbers topological field quantum is characterized by a fractal quantum number m, which roughly tells which power of fixed scaling is applied to standard topological field quantum to obtain the topological field quantum in question. An interesting possibility is that m might be related with p-adic scaling $x \to p^m x$. For a detailed definition of vacuum quantum numbers the reader can consult the appendix of this book.

6.2 Vacuum quantum number changing phase transitions and morphogenesis

In ordinary physics space-time is a fixed arena for the dynamics of the quantum fields. The space-time serves as a master and fields serve as slaves. The enormous vacuum degeneracy of the Kähler action suggests that the situation might be just the opposite for bio-systems in the TGD Universe. If the space-time surface is a small deformation of a vacuum extremal, there is indeed a good reason to expect a large ground state degeneracy (spin glass analogy) in the sense that ground states correspond to different configurations for 3-surfaces. In the bio-systems, the order parameter associated with some macroscopic quantum system could induce changes between these ground states and thus give rise to the changes of the macroscopic geometry and even the topology of the space-time sheet.

Suppose that the order parameter, serving as a master, changes so that the covariant constancy condition for the order parameter characterizing the ground state of the supra phase is not satisfied anymore. As a consequence, space-time topology changes, new join along boundaries bonds are created and old are destroyed. The end result is that covariant constancy condition is satisfied in the final state. The size, shape and even the topology of the organ could change in this kind of phase transition. Self-organization is expected to lead to an asymptotic states in which covariant constancy conditions hold true. These covariant constancy conditions in time direction and in the direction of Josephson junction are indeed absolutely essential in the general model of Josephson junction leading to Sine-Gordon equation.

6.3 Vacuum quantum numbers and the size of the organ

The appendix of this book provides detailed information about vacuum quantum numbers (form more details see [D7]). Besides two Poincare quantum numbers (ω_i, n_i, k_i) $i = 1, 2$, there is also fractal quantum number m characterizing the members in a family of topological field quanta

obtained from basic topological field quantum by iterating discrete scaling whose magnitude depends on topological field quantum. The considerations "Macroscopic quantum phases..." suggest that various bio-molecules and the structures formed by them correspond to the value of $\omega_1 = (10^{2.5} - 10^3)m_p$ and that cell and cell membrane could be identified as corresponding to structures having the values of fractal quantum number $m = 0$ and $m = 2$ respectively and $\omega_1 = (10^5 - 10^6)m_p$. There are good reasons to expect that larger organs correspond to larger values of ω_1 and that surface structures in general correspond to larger values of the fractal number.

There are reasons to expect that the value of ω_1 at the atomic condensation level is very rigid. At the other condensation levels the situation is not so clear but absolute minimization of Kähler action implying generalized Bohr rules together with quantum self-organization suggests that the values occurring in nature vary in very strict bounds. The fact that cell sizes vary between certain limits (typically $10^{-6} - 10^{-5}$ meters) might result from the variation of ω_1 by a factor of ten. If this is the case the growth of an organ or organelle, say cell, would correspond to a gradual increase of the parameter ω_1 at the appropriate level of condensation. It would be tempting to postulate that the variations in the value of ω_1 become larger the higher the level of condensation is.

Homology is a very general biological phenomenon. Same basic structure (for instance five fingers, spinal cord, etc..) appears with various sizes and detailed forms in different species. The simplest explanation is that these structures develop from identical initial structures but that the values of the vacuum quantum numbers, in particular ω_1 and possibly also the fractal quantum number m are different for these structures, so that the critical sizes are different. The differing sizes of the individuals belonging to the same species could be explained in a similar manner although the values of the other vacuum parameters affect the size, too. Fractal quantum number m might explain the fractal structures observed in the organic matter at the higher condensation levels [20].

6.4 Phase transitions changing the values of the vacuum quantum numbers

The surface density of the # contacts is constant in the stationary situation. The larger the electromagnetic charge of the space-time sheet, the larger the total number $N(\#)$ of the # contacts near its boundaries. The perturbation of the # contact surface density is expected to lead to the in-stability in the shape and possibly also the size of the 3-surface if 3-surface corresponds to a small deformation of a vacuum extremal. One can also consider the possibility that the 3-surface contains some critical regions near vacuum extremals. An attractive simplifying hypothesis is that the 3-surface suffers a rapid deformation in such a manner that the surface density $n(\#)$ of the # contacts is constant in the final situation. For instance, the reduction of # contact density at some section of a linear structure would generate a pinch and could lead to the splitting of the structure. This kind of mechanism is expected to lead to the splitting of the join along boundaries contacts.

Bio-systems consist mostly of water and hydrodynamics flows are in a good approximation incompressible, so that only the shape of the 3-surface is controllable. This suggests that, at least for sufficiently large space-time sheets, the volume of a given sheet of the 3-space is proportional to the number $N(\#)$ of the # contacts:

$$V = kN(\#) = kn(\#)A \ ,$$

so that the surface density of the # contacts would behave as

$$n(\#) = \frac{V}{kA} \ .$$

The smaller the surface density of the # contacts, the larger the surface area per volume and the more fractal the appearance of the surface. This is in accordance with the idea that for small surface densities of # contacts (and small total electromagnetic charges) 3-surface is nearer to a vacuum extremal and therefore the shape of the 3-surface becomes unstable.

These considerations suggests that the generation of the gradients in the density of # contacts or some other super conducting particles through the generation of the supra currents provide a control mechanism for the shape of the organ. Since # contacts couple to the difference ΔA of the classical gauge potentials associated with the two space-time sheets connected by # contacts, the changes in ΔA induce a change in the shape of the 3-surface. There is also a coupling to the difference of the order parameters (effectively classical gauge potentials) describing the topologically condensed coherent photons on the two space-time sheets in question. This could make possible for a coherent state of photons, perhaps generated by micro-tubuli and/or some other linear structures, to control the shape of the 3-surface.

The phase information is expected to be important even in the long length scales. A classic example, giving striking evidence for the presence of the complex order parameter in even macroscopic length scales, is related to the growth of a new "leg" or, actually its homological equivalent in lower organisms. The detailed description can be found in the book of Winfree [31]. Suppose one removes left leg and replaces it with the right one. What happens is that two additional left legs grow! The explanation is based on the conservation of the phase difference around a circle surrounding the leg in the sense that this phase difference is constant along the leg. This quantum number is opposite for left and right legs: $n(L) = -n(R)$. In the situation considered the total quantum number is $2n(L) + n(R) = n(L)$.

At longer length scales, the changes of the vacuum quantum numbers affect the size and form of the organ.

1. The growth of the organ might correspond to a gradual increase of ω_1 and therefore of the stable size of corresponding field quantum.

2. A phase transition leading to a decrease of the quantum number ω_1 can take place for field quantum and reduces the size of a stable field quantum: this kind of phase transition implies the decomposition of the developing embryo into several sub-organs during morphogenesis.

To make these ideas more concrete consider some examples.

1. Cell division is the simplest example of a generation of a new structure and is difficult to understand in terms of purely biochemical concepts. The generation of the cellular membrane takes place spontaneously, when the mass of the growing cell becomes larger than some critical mass. The simplest model for the cell division is based on the decrease of the vacuum quantum number ω_1 at the cell level, so that the critical size of the cell decreases and cell divides. During the growth ω_1 increases until the critical cell size is achieved. At the first level of condensation the phase transition decreasing ω_1 must be triggered by some kind of an "alarm clock" to be discussed below.

2. Differentiation: the developing embryo divides at very early stage to a mosaic of separate regions, which later develop into various organs. Biochemical concepts do not throw much light to the description of this phenomenon and there are several indications [19] that the phenomenon is topological rather than biochemical. For example, the number of the regions stays constant although the size of the embryo increases and is stable against external perturbations and the number and general structure of the organs is same for all individuals of the species independently of their size. It is natural to identify these regions as topological field quanta, whose size is determined by the value of ω_1 and increases during the growth. The stability against external perturbations corresponds to the stability against topological changes.

6.5 Biological alarm clocks and morphogenesis

In previous section very general model for biological alarm clocks based on weakly coupled super conductors was proposed. This kind of circuits could be an essential element of morphogenesis. Some examples are in order to show that this idea might have relevance.

1. The replication of cell is an extremely complicated process but could be understood as quantum self-organization process leading to final state pattern which only very mildly depends on the initial state. This process must be initiated by a 'wake-up' of a self representing perhaps the cell. The alarm clocks must now be contained to the membrane surrounding the cell nucleus and probably also to the cell membrane since the cell membrane is known to be coupled to the division process of the cell nucleus, too [32]. The reference currents are generated, when the new cell is born. The process leading to the replication of the cell could involve a reduction of the density of some super-conducting charge carriers in the critical region and this could initiate the decay of the cell. This is achieved if Josephson currents run away from certain region of the membrane of the cell nucleus implying depletion of charge carriers.

2. The generation of a completely new spatial structures during the morphogenesis is second extremely complicated process which should be understandable in terms of quantum self-organization. An example is afforded by the generation of somites [19], which later give rise to brain and spinal cord. The homogenous longitudinal cell mass divides in a phase transition like manner into somites with clock wise regularity and the number of the somites is a constant characteristic for the species in question [19]. The catastrophe theoretic models proposed in [19] are based on the assumption that the pulse triggering the formation of somites is coupled to a biological clock, so that the motion of the boundary between differentiated and undifferentiated cell mass alternately slows down or fastens up and implies the generation of discrete regions, where the formation of the somites takes place.

A qualitative TGD based description is provided by the alarm clock model:

1. There is certain biorhythm realized using Josephson junctions (rhythms (minute scale) of this kind have indeed been identified [19]) at cell level.

2. Josephson currents flow between the cells belonging to the longitudinal cell mass and neighboring cells in transversal direction. Due to the presence of the cell level reference currents, Josephson currents interfere destructively and variations in density of charge carriers are small.

3. There is slow dependence of the phase of the order parameter ψ along the linear cell mass implying a phase lag between the clocks.

4. Reference current dissipates gradually through phase slippages and when the time is ripe the amplitude of the Josephson current becomes large and makes the density of charge carriers small inside the longitudinal region. The formation of the somites begins since the stability criterion implies that the stable size of topological field quantum decreases.

5. Time regulation is achieved through the presence of the biological clock: nothing happens unless the phase of the clock is correct since Josephson current runs to a "wrong" direction.

6. The process begins from the cells, which were born first since the clocks associated with them were created first and propagates in the order, in which the cells were born. In fact, the spatial dependence of the phase of the order parameter might code this order. The spatial dependence of the phase means that the rate for the propagation of the somite formation

varies with position and guarantees in this manner the formation of spatially separated structures (compare with clock wave front model of [19]). The number of the somites is just the multiple of 2π:s that the phase of the order parameter increases along the longitudinal cell mass.

6.6 Could vacuum quantum numbers control gene expression via Josephson currents

Controlled and synchronized gene expression is the most fundamental aspect of morphogenesis and implies surprising determinism of the development. When developing organism achieves certain level of development, certain gene activates. This requires feedback mechanism from long length scales of size of order organ to the gene level. In standard physics, the most plausible mechanisms are chemical. Certainly it is very difficult to understand how organs size could control the activation of genes via chemical concentrations. Whether this is the case is an unanswered question as yet. In any case, the notion of many-sheeted space-time provides a fresh view to this process.

TGD leads to the notion of many-sheeted DNA [L2] which means that DNA has # contacts to several space-time sheets. One can even consider the possibility that various space-time sheets associated with gene correspond to the expression domains of gene so that in a very abstract sense genome would be full grown organism compressed to a thin many-sheeted thread of thickness of order 10^{-8} meters and morphogenesis could be regarded as a decompression of this packed information. If self-organization determines what happens in transversal degrees of freedom, then one could say that gene codes the one-dimensional skeleton of the expression domain of the gene. Especially interesting from the point of view of bio-control are join along boundaries contacts connecting DNA space-time sheets with larger space-time sheets.

Many-sheeted space-time concept suggests hierarchies of biological alarm clocks whose ringing induces ringing of some clocks at a lower level of hierarchy so that finally the alarm clock waking-up and activating definite gene rings. A possible mechanism causing the ringing would be situation in which the potential difference associated with the Josephson junction becomes equal to the energy difference of a single particle state associated with either super-conductor: cyclotron resonance, which seems to be crucial for brain functioning and EEG, is basic example of this. This could at DNA level lead to the activation of gene and start up of a self-organization process. One could imagine complicated circuits in which ringing would occur only provided all required conditions are achieved. It must be emphasized that this option is not the only possible one and in [M3] a more plausible mechanism involving the new physics implied by TGD is developed.

The correlation of gene expression with the size of growing organ could be achieved as follows. If the potential difference corresponds to the difference of vacuum frequencies ω_1 associated with the coupled super conductors and if ω_i correlate with the sizes of the corresponding structures, the ringing of the clock would occur when the size difference is critical. If the first super conductor corresponds to some structure with a fixed size (say gene) and second super conductor corresponds to the growing organ, this mechanism would initiate new kind of gene expression when the growing organ reaches critical size.

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