TGD Inspired Model for Nerve Pulse

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Abstract

The basic idea behind the model of nerve pulse is that some kind of quantum jump reduces the magnitude of membrane potential below the threshold leading to the generation of nerve pulse. Several identification of this quantum jump have been discussed during years but no really convincing option has been found. The evolution of ideas about dark matter hierarchy and associated hierarchy of Planck constants led to a breakthrough in several sectors. The assignment the predicted ranged classical weak and color gauge fields to dark matter hierarchy was the crucial step and led among other things to a model of high T_c superconductivity predicting the basic scales of cell, to a generalization of the genetic code to a hierarchy of genetic codes.

1. Background

The basic philosophy behind the model is following.

a) In TGD Universe the function of EEG and its variants is to make possible communications from the cell membrane to the magnetic body and the control of the biological body by the magnetic body via magnetic flux sheets traversing DNA by inducing gene expression. This leads to the notions of super- and hyper-genome predicting coherent gene expression at level of organs and population.

b) The assignment the predicted ranged classical weak and color gauge fields to dark matter hierarchy was a crucial step in the evolution of the model, and led among other things to a model of high T_c superconductivity predicting the basic scales of cell, and also to a generalization of EXG to a hierarchy of ZXGs, WXGs, and GXGs corresponding to Z^0, W bosons and gluons.

c) Dark matter hierarchy and the associated hierarchy of Planck constants plays a key role in the model. For instance, in the case of EEG Planck constant must be so large that the energies of dark EEG photons are above thermal energy at the physiological temperature. The assumption that a considerable fraction of the ionic currents through the cell membrane are dark currents flowing along the magnetic flux tubes explains the strange findings about ionic currents through cell membrane. Concerning the model of nerve pulse generation, the newest input comes from the model of DNA as a topological quantum computer and experimental findings challenging Hodgkin-Huxley model as even approximate description of the situation.

d) The identification of the cell interior as gel phase containing most of water as structured water around cytoskeleton - rather than water containing bio-molecules as solutes as assumed in Hodkin-Huxley model - allows to understand many of the anomalous behaviors associated with the cell membrane and also the different densities of ions in the interior and exterior of cell at qualitative level. The proposal of Pollack that basic biological functions involve phase transitions of gel phase generalizes in TGD framework to a proposal that these phase transitions are induced by quantum phase transitions changing the value of Planck constant. In particular, gel-sol phase transition for the peripheral cytoskeleton induced by the primary wave would accompany nerve pulse propagation. This view about nerve pulse is not consistent with Hodkin-Huxley model.

2. New view about nerve pulse generation

The basic hypothesis has been that quantum jump takes the resting potential below the threshold for the generation of nerve pulse. One can imagine several manners for how this could happen. Quite recently I learned that nerve pulse propagation seems to be an adiabatic process and thus does not dissipate: the authors propose that 2-D acoustic soliton is in question. Adiabaticity is what one expects if the ionic currents are dark currents (large $\hbar$ and low dissipation) or even supra currents. Furthermore, Josephson currents are oscillatory so that no pumping is needed. Combining this input with the model of DNA as topological quantum computer (tqc) leads to a rather precise model for the generation of nerve pulse.

a) The system would consist of two superconductors- microtubule space-time sheet and the space-time sheet in cell exterior- connected by Josephson junctions represented by magnetic flux tubes defining also braiding in the model of tqc. The phase difference between two super-conductors would obey Sine-Gordon equation allowing both standing and propagating solitonic solutions. A sequence of rotating gravitational penduli coupled to each other would be the mechanical analog for the system. Soliton sequences having as a mechanical analog penduli rotating with constant velocity but with a constant phase difference between them would generate moving kHz synchronous oscillation. Also moving oscillations in EEG range can be considered and would require larger value of Planck constant in accordance with vision about evolution as gradual increase of Planck constant.

b) During nerve pulse one pendulum would be kicked so that it would start to oscillate instead of rotating and this oscillation pattern would move with the velocity of kHz soliton sequence. The velocity of kHz wave and nerve pulse is fixed by periodic boundary conditions at the ends of the axon implying that the time spent by the nerve pulse in traveling along axon is always a multiple of the same unit: this implies kHz synchrony. The model predicts the value of Planck constant for the magnetic flux tubes associated with Josephson junctions and the predicted force caused by the ionic Josephson currents is of correct order of magnitude for reasonable values of the densities of ions. The model predicts kHz em radiation as Josephson radiation generated by moving soliton sequences. EEG would also correspond to Josephson radiation: it could be generated either by moving or standing soliton sequences (latter are naturally assignable to neuronal cell bodies for which $\hbar$ should be correspondingly larger): synchrony is predicted also now.

c) The previous view about microtubules in nerve pulse conduction can be sharpened. Microtubular electric field (always in the same direction) could explain why kHz and EEG waves and nerve pulse propagate always in same direction and might also feed energy to system so that solitonic velocity could be interpreted as drift velocity. This also inspires a generalization of the model of DNA as tqc sine also microtubule-cell membrane systems are good candidates for performers of tqc. Cell replication during which DNA is out of game seems to require this and microtubule-cell membrane tqc would represent higher level tqc distinguishing between multi-cellulars and mono-cellulars.

d) New physics would enter in several manners. Ions should form Bose-Einstein cyclotron condensates. The new nuclear physics predicted by TGD predicts that ordinary fermionic ions (such as K^+, Na^+, Cl^-) have bosonic chemical equivalents with slightly differing mass number. Anomalies of nuclear physics and cold fusion provide experimental support for the predicted new nuclear physics. Electronic supra current pulse from microtubules could induce

the kick of pendulum inducing nerve pulse and induce a small heating and expansion of the axon. The return flux of ionic Josephson currents would induce convective cooling of the axonal membrane. A small transfer of small positive charge into the inner lipid layer could induce electronic supra current by attractive Coulomb interaction. The exchange of exotic W bosons which are scaled up variants of ordinary $W^{\pm}$ bosons is a natural manner to achieve this if new nuclear physics is indeed present.

3. The function of neural transmitters

TGD leads to a general view about the functions of membrane oscillations, nerve pulse and neural transmitters. Electromagnetic membrane oscillations induced by Z^0 MEs provide a realization of the memetic code as a fundamental cognitive code. The binding of various information molecules to the corresponding receptors gives rise to neuronal qualia analogous to tastes and odors but providing information about external world whereas ordinary receptors give information about nearby environment. At our level of hierarchy these qualia probably correspond to emotions in consistency with the finding that neurotransmitters can be identified as information molecules. Neurotransmitters might be also seen as conscious links in quantum web. The view that inhibition actually requires active energy feed and that excitation occurs automatically in the absence of the energy feed and induces entanglement with environment, is defended. This view conforms with Huxley's vision about brain as a filter inhibiting conscious experiences.

4. Empirical evidence for axonal super-conductivity

A p-adic hierarchy of super-conductivities is the basic prediction of TGD inspired model of living matter. The many-sheeted model of the effective electronic super-conductivity explains at quantitative level the findings of Hafedh Abdelmelek and his group about the reduction of the axonal resistivity in the range of physiological temperatures. Although the original model is probably non-realistic the observations are consistent with the recent views about nerve pulse.

5. Microtubular level

The view about what happens at the micro-tubular level during synchronous neuronal firing relies on a many-sheeted model for sol-gel phase transitions as conscious bits and on the seesaw mechanism of remote metabolism according to which sol-gel transitions induces gel-sol transitions elsewhere in the cell and vice versa. Micro-tubular surfaces can be seen as analogs of cortical sensory and motor areas providing kind of conscious log files about sensory and motor history of the cell in terms of conformational transitions of tubulin dimers representing conscious bits.

What happens at the micro-tubular level during the nerve pulse, how gel phase differs from sol phase, and what occurs in sol-gel transition, belong to the principal challenges for quantum theories of consciousness. Charge entanglement associated with various bosonic ions allows to tackle these questions. The Bose-Einstein condensates of hydrogen atoms at tubular $k = 139$ space-time sheets form a bundle behaving like a liquid crystal identifiable as the gel phase. Positive and negative energy IR photons at energy of .1 eV belong to the predicted fractal hierarchy of metabolic currencies, and allow to control the stability of this B-E condensate so that a precisely targeted control of the cellular state by local sol-gel transitions becomes possible. Albrecht-Buehler has demonstrated that photons with this energy have a maximal effect on cells.

Negative energy MEs are especially important: they make possible intentional action at the micro-tubular level, they are crucial for the understanding of the micro-temporal quantum coherence, and have also inspired the notions of remote metabolism and quantum credit card. The newest discovery along this line is what might be called seesaw mechanism of energy metabolism. Seesaw mechanism minimizes dissipative losses and allows to understand how micro-tubular surfaces provide dynamical records for the cellular sol-gel transitions, and thus define fundamental micro-tubular representation of declarative long term memories. Also the notion of micro-tubuli as quantum antennae becomes precisely defined.

The model of DNA as topological quantum computer brings in a new element. Microtubule-axonal membrane system could perform topological quantum computation just as DNA-membrane (nuclear and perhaps also cell membrane) system has been proposed to do. The braiding of the magnetic flux tubes connecting microtubules to axon would define tqc programs and also provide a representations for sensory input from sensory organs in time scale shorter than millisecond if one assumes that gel-sol-gel transition of microtubule accompanies the nerve pulse. Whether one it one say that nerve pulse is initiated at microtubular or axonal level or by both collectively is not clear since the magnetic flux tubes connecting these two systems make them to act like single coherent whole.

1 Introduction

The model of nerve pulse has developed through several tortuous twists reflecting the development of the basic ideas of TGD inspired theory of consciousness and of bio-systems as macroscopic quantum systems. The chapters about EEG and ZEG provide a necessary background for the model of nerve pulse. The chapters [M4, M5] written before dark matter revolution provide a detailed discussion of basic aspects of EEG. The newest chapter [M3] related to EEG provides a very general vision about the hierarchy of EEGs based on dark matter hierarchy and about its generalization to ZEG and even WEG (Z and W denote for dark Z^0 and W boson fields with interaction range which can be arbitrary long at higher levels of dark matter hierarchy). This model derives from the model of bio-superconductivity as quantum critical high T_c super-conductivity [J1, J2, J3]. The consistency with the model of DNA as topological quantum computer [L7] poses additional strong constraints on the model.

The basic hypothesis has been that quantum jump takes the resting potential below the threshold for the generation of nerve pulse. One can imagine several manners for how this could happen.

1. The first idea was that axonal membrane acts as a Josephson junction and that a soliton propagating along it induces the nerve pulse. The model for the high T_c electronic superconductivity allowed to construct a detailed model for this Josephson junction and "timelike" and possibly also space-like soliton sequences are indeed present. Time-like soliton sequences however represent oscillations at a frequency of order 10^{13} Hz. For the scaled up dark matter variants of cell membrane Josephson junction at $k = 4$ level of dark matter hierarchy standing EEG waves at 5 Hz frequency can be identified as Josephson oscillations. It is however clear that moving solitons cannot correspond to nerve pulses.

2. The next working hypothesis was that Z^0 massless extremals (MEs, topological light rays) drifting along axon induce the nerve pulse. It became clear that this model [18] cannot be the whole truth although a pulse propagating along Z^0 or em MEs parallel to axon combined with drifting of ME cannot be excluded as initiator of the nerve pulse. In the recent model this idea is given up.

3. Dark matter revolution led to a much more elegant looking idea. Nerve pulse is generated as the charged entanglement induced by W MEs connecting magnetic body and cell interior is reduced in a quantum jump leading to a state in which cell interior receives a positive exotic charge due to exotic ionization of a Bose Einstein condensate of the bosonic ions so that the value of the resting potential is reduced below the critical level. This process would occur only at the axonal hillock and one might hope that the rest would be more or less ordinary biochemistry. This need not be the case as the strange findings about ionic membrane currents discussed in [J3] demonstrate. It turns out that exchange of W bosons could indeed be the primary cause of nerve pulse generation but that also other options are possible.

4. Quite recently I learned [66, 67, 68, 69, 70] (thanks to Ulla Mattfolk) that nerve pulse propagation seems to be an adiabatic process and thus does not dissipate: the authors propose that 2-D acoustic soliton is in question. Adiabaticity is what one expects if the ionic currents are dark currents (large $\hbar$ and low dissipation) or even supra currents. Furthermore, Josephson currents are oscillatory so that no pumping is needed. Combining this input with the model of DNA as topological quantum computer (tqc) [L7] leads to a rather precise model for the generation of nerve pulse.

1.1 General vision about living matter as a macroscopic quantum system

The following assumptions summarize the general vision achieved before the dark matter revolution. The picture is consistent with the findings of Libet about strange time delays of consciousness [52, 53] discussed in the article "Time, Space-time and Consciousness" in [17] and chapter [K1].

1. Magnetic bodies forming a hierarchy are the fundamental volitional agents transforming intentions to actions. Intentions are represented by p-adic MEs transformed to negative energy MEs representing the desire about particular activity communicated to the lower level magnetic bodies in the geometric past and eventually to the material body. Each negative energy ME in the cascade represents a desire to realize some submodule in motor program. Eventually the cascade of negative energy MEs ends up to the glial cells serving as metabolic sources. The desired action is generated in terms of neural communications and of positive energy MEs both representing classical communications to the geometric future. The desire in question could be a desire to perform a particular motor action, a desire to direct attention or select among sensory percepts (binocular rivalry is the standard example), or a desire to remember something. Sensory perception, motor action, and memory would thus be based on essentially the same basic mechanism. The population inverted many-sheeted laser system providing the energy source in brain or body would consist of bosonic ions or of Cooper pairs of fermonic ions in excited cyclotron states.

2. Sensory representations are realized at the magnetic bodies associated with the sensory organs and sensory mental images are shared with the personal magnetic body by negative energy em MEs. Brain constructs only symbolic and cognitive representations, writes the sensory music to notes. The mental images defined by these representations can be shared by personal magnetic body or magnetic bodies associated with the sensory organs in a similar manner. Also classical communications to the personal magnetic body are possible. A tree like structure with the root represented by sensory mental images and branches and leaves represented by various symbolic and cognitive mental images results.

   The selective entanglement by negative energy MEs allows to understand the active aspects of sensory experience involving direction of attention and selection between percepts at various levels. In the case of motor actions, the negative energy MEs received from magnetic body communicate the desires of the magnetic bodies about motor actions to be performed and the response by positive energy MEs would realize these desires as nerve pulse patterns.

3. Positive energy interior MEs lie along interior of magnetic flux tubes of the personal magnetic body. These MEs could relate to the classical communication of the symbolic representations constructed from the data processed in the brain to the magnetic body. Sensory perception and memory differ only is that the time scale involved is different. Declarative memory corresponds to negative energy MEs sent from a point of the personal magnetic body at the distance $L = cT$ to the material body and reflected back as positive energy MEs. Thus the material body serves as the mirror unlike in the original variant of the mirror mechanism

of memory. The distance $L = cT$ along magnetic flux proportional to the transverse area S of the flux tube $L \propto S$ tubes codes for the temporal distance to the geometric past by transforming it to cyclotron frequency scale.

1.2 A general view about quantum control, coordination and communication inspired by dark matter hierarchy

The following general overview about quantum communication and control emerges from the model for EEG hierarchy as correlate for dark matter hierarchy discussed in detail in [M3].

1. Cyclotron frequencies relate to the control of the biological body by the magnetic body and could be assigned with the magnetic flux sheets going through DNA since it is genome where protein synthesis is initiated and is thus the optimal intermediate step in the cellular control.

2. One of the basic functions of cell membranes is to perceive the chemical environment using various kinds of receptors as sensors. Neurons have specialized to receive symbolic representations of the sensory data of primary sensory organs about the situation in the external world. A good guess is that in this case magnetic flux quanta are hollow cylindrical structures serving as templates for axons and possibly other similar structures and define the communication lines connecting cell membranes to the magnetic body.

3. This picture would explain why the temperature of brain must be in the narrow range 36-37 K to guarantee optimal functionality of the organism. If interior superconductivity is lost, magnetic body receives sensory data but is paralyzed since its desires cannot be realized. If boundary superconductivity is lost, magnetic body can move but is blind.

4. In the length scales below the weak length scale L_w also charged weak bosons behave as massless particles and the exchange of virtual W bosons makes possible a nonlocal charge transfer. Dark quark-antiquark pairs associated with the color bonds of the atomic nuclei can become charged via the emission of dark W boson and thus produce and exotic ion. The same can happen at the higher levels of dark matter hierarchy.

5. Massless extremals (MEs, topological light rays) serve as correlates for coherent states and Bose-Einstein condensates of dark bosons. Besides neutral massless extremals (MEs) TGD predicts also charged massless extremals obtained from their neutral counterparts by a mere color rotation (color and weak quantum numbers are not totally independent in TGD framework). The second nonlocal quantum control mechanism is based on em charge entanglement involving a superposition of ordinary ions/atoms and exotic ions connected by a W massless extremal joining magnetic body and biological body. In quantum jump this state would be reduced to exotic charge state with some probability increasing with the strength of the classical W field. Charged massless extremals could be seen as correlates for nonlocal quantum control by affecting charge equilibria whereas neutral MEs would serve as correlates for coordination and communication. Color charged MEs could also induce color charge polarization and flows of color charges and thus generate visual color qualia by the capacitor mechanism discussed in [K3].

6. These nonlocal quantal mechanisms can induce or change electromagnetic polarization in turn inducing ordinary charge flows and thus making possible quantum control of nervous system by magnetic body. The generation of nerve pulse could rely on the spontaneous state function reduction occurring for charge entangled state reducing the resting potential below the critical value by this kind of mechanism inducing charge transfer between cell interior and exterior. Also remote mental interactions, in particular telekinesis, might rely on this mechanism.

1.3 The role of electronic super-conductivity

1.3.1 General mechanisms of bio-superconductivity

The many-sheeted space-time concept provides a very general mechanism of superconductivity based on the 'dropping' of charged particles from atomic space-time sheets to larger space-time sheets. The first guess was that larger space-time sheets are very dry, cool and silent so that the necessary conditions for the formation of high T_c macroscopic quantum phases are met.

The possibility of large $\hbar$ quantum coherent phases makes however the assumption about thermal isolation between space-time sheets un-necessary. This isolation might of course be present and make possible ionic super-conductivity. At larger space-time sheet the interactions of the charged particles with classical em fields generated by various wormhole contacts feeding gauge fluxes to and from the space-time sheet in question give rise to the necessary gap energy. The simplest model for Cooper pair is space-time sheet containing charged particles having attractive Coulombic interaction with the quarks and antiquarks associated with the throats of the wormhole contacts.

A crucial element is quantum criticality predicting that new kind of superconductivity, "boundary superconductivity", appears at the fluctuating boundaries of competing ordinary and large $\hbar$ phases for nuclei besides large $\hbar$ variant of ordinary superconductivity in the interior. The Cooper pairs of interior and boundary supra currents are different with interior Cooper pairs being BCS type. These two superconducting phases compete in certain narrow interval around critical temperature for which body temperature of endotherms is a good candidate in the case of living matter. Also high T_c superfluidity of bosonic atoms dropped to space-time sheets of electronic Cooper pairs becomes possible besides ionic super conductivity. Even dark neutrino superconductivity can be considered below the weak length scale of scaled down weak bosons.

Magnetic and Z^0 magnetic flux tubes and sheets are especially interesting candidates for dark supra current carriers and might define Josephson junctions. In this case the Cooper pairs must have spin one and this is indeed possible for wormholy Cooper pairs. The fact that the critical magnetic (Z^0 magnetic) fields can be very weak or large values of $\hbar$ is in accordance with the idea that various almost topological quantum numbers characterizing induced magnetic fields provide a storage mechanism of bio-information.

This mechanism is extremely general and works for electrons, protons, ions, charged molecules and even exotic neutrinos and an entire zoo of high T_c bio-superconductors, super-fluids and Bose-Einstein condensates is predicted. Of course, there are restrictions due to the thermal stability it room temperature and it seems that only electron, neutrino, and possibly proton Cooper pairs are possible at room temperature. The effects of ELF em fields on vertebrates suggest that Bose-Einstein condensates of all bosonic ions and their exotic counterparts resulting when some nuclear color bonds become charged [F9] are there but the model of high T_c super-conductivity does not favor them. It is of course possible that the temperature at dark magnetic space-time sheets is lower than at the visible space-time sheets.

1.3.2 Bose-Einstein condensates at magnetic flux quanta in astrophysical length scales

The new model for the topological condensation at magnetic flux quanta of endogenous magnetic field $B = .2$ Gauss is based on the dark matter hierarchy with levels characterized by the value of $\hbar(k_d) = \lambda^{k_d}\hbar_0$, $\lambda = 2^{11}$. Much more general values of λ are possible and some of them probably realized but these appear in the model of EEG.

1. There are several levels of dynamics. In topological condensation the internal dynamics of ions is unaffected and $\hbar$ has the ordinary value. The formation of Cooper pairs involves dynamics at $k_d = 1$ level of dark matter hierarchy. Also the dynamics of ionic Cooper pairs

remains unaffected in the topological condensation to magnetic flux quanta obeying $k_d > 1$ dynamics.

2. Cyclotron energies scale as as λ^{k_d} so that for a sufficiently high value of k thermal stability of cyclotron states at room temperature is achieved. Spin interaction energy $\mu \cdot B \propto S \cdot B$ scales as $1/\hbar$ since four-momentum and angular momentum are by Poincare symmetry invariant under the scaling of $\hbar$ (the highly non-trivial implications of the invariance of angular momentum are discussed in [C6]). Hence spin interaction energy has the ordinary value. Unless thermal isolation is assumed, spin degrees of freedom are thermalized, and only cyclotron degrees of freedom can be quantum coherent. This is a testable prediction distinguishing between the new and old model.

3. If the flux quanta of $B = .2$ Gauss correspond to $k_d = 4$ level of dark matter hierarchy, cyclotron energies $E = (\hbar/2\pi) \times ZeB/Am_p$ are scaled up by a factor $\lambda^4 \simeq 2^{44}$ from their ordinary values and are above thermal energy at room temperature for $A \leq 233Z$, where Z is the charge of the ion. Even for $Z = 1$ this includes all stable nuclei. Bose-Einstein condensates of bosonic ions are thus possible at room temperatures at Earth's surface. Cooper pairs of fermionic ions are possible only for $A \leq 4$ leaving in practice only protons into consideration at room temperature: the temperature at dark space-time sheets could of course be lower than physiological temperature.

1.3.3 Experimental evidence for bio-superconductivity

From the beginning it has been obvious that super-conductivity serves some important function in nerve pulse conduction. For instance, Josephson currents are optimal for quantal alarm clocks [M4]. Already before the ideas inspired by the dark matter hierarchy the contact by Hafedh Abdelmelek and his group [54] led to a crucial step of progress in the understanding of this function. It became clear that genuine or effective electronic super-conductivity (in the sense that Cooper pairs are dropped temporarily to larger space-time sheets implying dissipation) is most probably involved with the propagation of the nerve signal through the myelin sheathed portions of the axon.

The resulting simple model explained the experimental findings at quantitative level correctly and makes several predictions. In particular, one can understand why physiological temperature can have only a rather restricted range. The breaking of the electronic super-conductivity is an essential aspect of the ordinary nerve pulse conduction in this model. Also the distinction between poikilotherms (such as frog) and endotherms (such as rabbit) can be understood. As it often happens, the most recent model is not consistent with this model but is preferred by its simplicity.

1.3.4 Strange findings about cell membrane

There are very strange findings challenging the notions of ionic pumps and channels [33, 39, 40, 34], and suggesting a mechanism dramatically reducing the metabolic costs involved with the ionic pumping. Second finding is that ionic currents seem to be quantal and are same for polymer membrane than for cell membrane! A further strange finding [66] is that the propagation of nerve pulse does not cause heating of the cell membrane implied by the model of nerve pulse based on chemistry. This suggests that dissipation is absent also during nerve pulse propagation and that the process might not be chemical as assumed hitherto.

One can imagine two explanations.

1. The first explanation would be that ionic currents are actually dark supra currents flowing along larger space-time sheet connecting cell interior and exterior. The model of high T_c super conductivity favors only electronic and protonic super conductivity at room temperature [J1] whereas the model for EEG favors the presence of Bose-Einstein condensates of ions. Bosonic

ions are required: the new nuclear physics predicted by TGD [F9] allows to assign to fermionic ions their bosonic chemical equivalents. Even permanent connections with the cell exterior (by magnetic flux tubes, say) are possible since Josephson currents oscillate. One can of course consider the possibility that dissipation rate is small due to the large value of Planck constant even in the absence of super conductivity. Also the temperature could be lower at the magnetic flux tubes containing dark ions but this assumption will not be made.

2. Second model that one can imagine relies on the exotic nuclear physics predicted by nuclear string model [F9] and the predicted hierarchy of fractally scaled up variants of weak interaction physics. If weak interactions can be present in cell length scales, the exchange of virtual or real $W^{\pm}$ bosons between nuclei could induce purely quantal and non-dissipative charge transfer between cell interior and exterior. Also charge entanglement becomes possible. The emission of $W^{\pm}$ would modify the nucleus to an exotic charged state in which one of the neutral color bonds connecting nucleons is charged. Since W exchange does not depend on cell membrane at all, the prediction would indeed be that ionic currents do not depend at all on the membrane in question. The model of nerve pulse however suggests that W exchange can have only a role of a control signal.

One can argue that pumps in case of ordinary matter are needed only when the cell interior and exterior are connected by join along boundaries bonds and that this connection is built only for diagnostic purposes in order to measure the concentrations of ions by measuring the ionic currents by their dissipation. The remote metabolism made possible by many-sheeted lasers reduces further the energy costs when pumping actually occurs.

1.4 The role of MEs and magnetic flux tube circuitry

The developments in the understanding of the role of MEs and magnetic flux tube circuitry have repeatedly forced to rethink the model of nerve pulse and EEG.

1.4.1 Universe as a conscious hologram

1. The notion of conscious hologram means that Universe is an extremely complex fractal Feynmann diagram with lines replaced by 4-dimensional space-time sheets and MEs are particular kinds of lines analogous to photon lines. These lines are like laser beams, which interfere in the vertices of the Feynmann diagram: vertices correspond to material space-time sheets, atoms, molecules, ..., cells, ... Super-conducting magnetic flux tubes are also important and act effectively as wave guides along which MEs propagate.

2. Topological field quantization allows to assign to any material system a field (magnetic) body. The view that "me" corresponds to the personal magnetic body of an astrophysical size receiving information from the material body by both classical communications and by sharing of the mental images realized in terms of bound state entanglement having negative energy MEs as a space-time correlate, has become a key hypothesis in the attempts to understand the functions of nerve pulse and EEG. The idea about brain as the sole seat of consciousness is deeply rooted in scientific thinking, and it took some time before I was able to take really seriously the idea about magnetic body as an intentional agent controlling the material body serving as its sensory and motor organ. In this respect the latest developments occurred while writing this article.

3. MEs, in particular, the topological field quanta of ELF em and Z^0 fields are in a crucial role as far as the understanding of EEG (and the predicted ZEG and WEG) is involved. After dark matter revolution it became clear that MEs are the natural correlates for coherent states

and Bose-Einstein condensates of dark matter bosons. It is still an open question whether ordinary laser light might be regarded as a special case of dark photons. Certainly the transformation of dark bosons to ordinary ones would occur through a de-coherence phase transition just like the transformation of laser light to ordinary photons.

1.4.2 Various kinds of MEs

One can imagine many kinds of MEs.

1. Interior MEs correspond to what might be called ELF MEs but they form only a small portion of the spectrum of MEs characterized by the fundamental frequencies defined by their lengths $f = c/L$ extended to ULF frequencies which correspond to length scales of order light lifetime. Also MEs in time scales at least down to 10^{14} Hz corresponding to visible photons are predicted be important.

2. Also boundary MEs identified as MEs attached to the boundaries of matter carrying space-time sheet and drifting along it quantum jump by quantum jump by a velocity $v < c$ can be considered and Z^0 MEs of this kind were in a key role in the previous model for nerve pulse generation. In the case of boundary MEs, which are assumed to be positive energy MEs, the effective phase velocity satisfies $v << c$, and from $f = v/L$ the sizes of the structures associated with a given frequency are smaller by a factor v/c.

3. Negative energy MEs, which correspond to phase conjugate laser light, make possible intentional action at the micro-tubular level, they are crucial for the understanding of the macro-temporal quantum coherence, and have also inspired the notions of remote metabolism and quantum credit card. The newest discovery along this line is what might be called seesaw mechanism of energy metabolism (see the article "Time, Space-time and Consciousness" in [17]). Phase conjugate laser beams [23, 24] seem to be the standard physics counterpart of negative energy em MEs and negative energy photons accompanying them.

4. Fractality implies that MEs contain MEs within MEs: this conforms with the general ideas about dark matter hierarchy and p-adic length scale hierarchy. MEs within MEs is the topological correlate for de-coherence of Fourier components of classical field. In the simplest situation MEs appear as pairs of high frequency and low frequency MEs. The scaling law of homeopathy [58] states that low frequencies are accompanied by high frequencies such that the frequency ratio has preferred predictable values identifiable as characteristic velocities in the system (such as EEG phase velocity): $f_{low}/f_{high} = v/c$. The most general assumption about the spectrum of high frequency MEs inside low energy MEs is that it is scale invariant in the sense that the intensity satisfies $I(f_{high}, f_{low}) = I(f_{high}/f_{low})$.

   Low frequency negative energy MEs could serve as correlates for remote quantum entanglement in cyclotron degrees of freedom. W MEs would make possible charged entanglement. High frequency MEs travel effectively like massless particles along the bridges defined by the low frequency MEs and can transform to boundary MEs serving as bridges between different space-time sheets at the receiving end, in which case their effective phase velocity is reduced to $v << c$. These MEs could induce a leakage of ions between different space-time sheets, breaking of super-conductivity and dissipative self-organization. This process which is analogous to the formation of hologram, is responsible for homeostasis and metabolism and gives rise to many-sheeted ionic flow equilibrium. Also many-sheeted lasers acting in a very wide range of frequencies become possible. The frequencies correspond to differences for the energies of ions at the space-time sheets involved. MEs parallel to axons can also act as Josephson junctions connecting space-time sheets which can correspond to different p-adic primes.

1.4.3 The strange effects of ELF em fields on vertebrates as a key to the model for hierarchy of EWEGs

The experimental findings of the pioneers of bio-electromagnetism [59] demonstrate that electromagnetic radiation at the harmonics of cyclotron frequencies of various ions in magnetic field $B = .2$ Gauss, in particular Ca^{+2} ion, are somehow involved with the bio-control. The dropping of ions from smaller space-time sheets to the super-conducting magnetic flux tubes of B indeed generates cyclotron radiation. The generalization of this mechanism [16, K2] explains the findings of Gariaev [60] about radio waves induced by laser irradiation of DNA. The detailed model explaining various aspects of these findings on basis of TGD inspired model of high T_c superconductivity led to a detailed model for the hierarchy of EWEGs (EW is for electro-weak) generated by Josephson junctions as Josephson and by cyclotron transitions of Bose-Einstein condensates of bosonic ions.

1.4.4 What could be the division of labor between different MEs?

To what kind of Z^0 MEs and em MEs correspond to has been one of the key questions for a long time. The evolution of ideas about dark matter hierarchy have led to the view that Z^0 MEs could serve as correlates for cognitive representations whereas em MEs correspond to as would correspond to sensory representations. This is of course highly speculative and must be taken with a big grain of salt.

Besides this also charged W MEs are present and the most natural identification would be as correlates for charged entanglement. The reduction of charge entanglement between magnetic body and biological body leads to to a final state involving exotic ions and charge non-equilibrium inducing ordinary currents. Hence charge entanglement is ideal for quantum control purposes. Thus motor-sensory dichotomy could naturally correspond to neutral-charged dichotomy for MEs. At least in the case of nerve pulses this seems a highly attractive hypothesis.

Dark photons could serve as a universal "sensory currency" allowing brain to generate virtual sensory percepts, at least in the case of "brain senses" like vision and olfaction. Dark Z^0 would in turn define universal cognitive currency. This picture conforms with the TGD based model of hearing which involves classical Z^0 fields in an essential manner [M6]. Charge entanglement made possible by W MEs would in turn be involved with motor actions understood in a very general sense. Already at the enzyme level long range weak interactions could be involved with what might be regarded as the bio-chemical counterpart of the motor control. In this picture cognition and motor control would rely on the new physics implied by the hierarchy of weak and color physics.

1.5 The most recent model for the generation of nerve pulse

Quite recently I learned [66, 67, 68, 69, 70] (thanks to Ulla Mattfolk) that nerve pulse propagation seems to be an adiabatic process and thus does not dissipate: the authors propose that 2-D acoustic soliton is in question. Adiabaticity is what one expects if the ionic currents are dark currents (large $\hbar$ and low dissipation) or even supra currents. Furthermore, Josephson currents are oscillatory so that no pumping is needed. Combining this input with the model of DNA as topological quantum computer (tqc) [L7] leads to a rather precise model for the generation of nerve pulse.

1. The system would consist of two superconductors- microtubule space-time sheet and the space-time sheet in cell exterior- connected by Josephson junctions represented by magnetic flux tubes defining also braiding in the model of tqc. The phase difference between two super-conductors would obey Sine-Gordon equation allowing both standing and propagating solitonic solutions. A sequence of rotating gravitational penduli coupled to each other would be the mechanical analog for the system. Soliton sequences having as a mechanical analog penduli rotating with constant velocity but with a constant phase difference between them would generate moving kHz synchronous oscillation. Periodic boundary conditions at the

ends of the axon rather than chemistry determine the propagation velocities of kHz waves and kHz synchrony is an automatic consequence since the times taken by the pulses to travel along the axon are multiples of same time unit. Also moving oscillations in EEG range can be considered and would require larger value of Planck constant in accordance with vision about evolution as gradual increase of Planck constant.

2. During nerve pulse one pendulum would be kicked so that it would start to oscillate instead of rotating and this oscillation pattern would move with the velocity of kHz soliton sequence. The velocity of kHz wave and nerve pulse is fixed by periodic boundary conditions at the ends of the axon implying that the time spent by the nerve pulse in traveling along axon is always a multiple of the same unit: this implies kHz synchrony. The model predicts the value of Planck constant for the magnetic flux tubes associated with Josephson junctions and the predicted force caused by the ionic Josephson currents is of correct order of magnitude for reasonable values of the densities of ions. The model predicts kHz em radiation as Josephson radiation generated by moving soliton sequences. EEG would also correspond to Josephson radiation: it could be generated either by moving or standing soliton sequences (latter are naturally assignable to neuronal cell bodies for which $\hbar$ should be correspondingly larger): synchrony is predicted also now.

3. The previous view about microtubules in nerve pulse conduction can be sharpened. Microtubular electric field (always in the same direction) could explain why kHz and EEG waves and nerve pulse propagate always in same direction and might also feed energy to system so that solitonic velocity could be interpreted as drift velocity. This also inspires a generalization of the model of DNA as tqc sine also microtubule-cell membrane systems are good candidates for performers of tqc. Cell replication during which DNA is out of game seems to require this and microtubule-cell membrane tqc would represent higher level tqc distinguishing between multi-cellulars and mono-cellulars.

4. New physics would enter in several manners. Ions should form Bose-Einstein cyclotron condensates. The new nuclear physics predicted by TGD [F9] predicts that ordinary fermionic ions (such as K^+, Na^+, Cl^-) have bosonic chemical equivalents with slightly differing mass number. Anomalies of nuclear physics and cold fusion provide experimental support for the predicted new nuclear physics. Electronic supra current pulse from microtubules could induce the kick of pendulum inducing nerve pulse and induce a small heating and expansion of the axon. The return flux of ionic Josephson currents would induce convective cooling of the axonal membrane. Clearly, the temperature at dark magnetic flux tubes could be lower than the physiological temperature. The model for the role of DC currents and potentials in healing discussed in [J7] suggests that metabolic energy quanta of order 1 meV are involved in bio-control so that the temperature at magnetic flux tubes containing ions could be by a factor of order 10^{-2} lower than the physiological temperature. A small transfer of small positive charge into the inner lipid layer could induce electronic supra current by attractive Coulomb interaction. The exchange of exotic W bosons which are scaled up variants of ordinary $W^{\pm}$ bosons is a natural manner to achieve this if new nuclear physics is indeed present.

1.6 What happens at the micro-tubular level during nerve pulse?

What happens at the micro-tubular level during the nerve pulse? How gel phase differs from sol phase? What occurs in sol-gel transition? These questions represent some of the principal challenges faced by quantum theories of consciousness.

There are two candidates for Bose-Einstein (BE) condensates associated with the ordered phases (say gel) of water. This derives from the fact that the zero point kinetic energy of hydrogen atom at

space-time sheet k is in a good approximation same as the zero point kinetic energy of an electronic Cooper pair at space-time sheet $k + 10$ (see the article "Time, Space-time, and Consciousness" in [17]). Thus both the BE condensates of hydrogen atoms at tubular $k = 139$ space-time sheets forming bundles behaving like liquid crystals and BE condensates of electronic Cooper pairs at $k = 149$ space-time sheets forming linear structures could accompany gel phase and ordered water phases. Positive and negative energy IR photons at energy of $\sim .125$ eV belong to the predicted fractal hierarchy of metabolic currencies, and allow to control the stability of this BE condensate so that a precisely targeted control of the cellular state by local sol-gel transitions becomes possible. Albrecht-Buehler [46] has demonstrated that photons with energy $E \sim .1$ eV have a maximal effect on cells.

The seesaw mechanism discussed in the article "Quantum model of sensory receptor" of [17] minimizes dissipative losses and allows to understand how micro-tubular surfaces could provide dynamical records for the cellular sol-gel transitions, and thus define a fundamental micro-tubular representation of declarative long term memories.

As far as nerve pulse is considered, one ends up with the proposal that the soliton propagating along axon might be a shadow of a more fundamental soliton propagating along microtubular surface and inducing gel-sol-gel transition meaning disassembly and reassembly of tubulins which induces a braiding of magnetic flux tubes coding the details of the sensory signal below millisecond time scale to the braiding pattern.

2 Exotic charge transfer between cell interior and exterior as fundamental control mechanism

The notions of ionic channels and pumps associated with the cell membrane are central for the standard cell biology [38]. There are however puzzling observations challenging this dogma and suggesting that the currents between cell interior and exterior have quantum nature and are universal in the sense that they not depend on the cell membrane at all [34, 35, 47, 39, 40]. One of the pioneers in the field has been Gilbert Ling [34], who has devoted for more than three decades to the problem, developed ingenious experiments, and written several books about the topic. The introduction of the book [33]) gives an excellent layman summary about the paradoxical experimental results.

It was a pleasant surprise to find that these experimental findings give direct support for the existence of an exotic charge transfer between cell interior and exterior.

Ionic supra currents and Josephson currents or the exchange of exotic W bosons could be in question. For the first option, the experimental data led to a model for cell homeostasis as a flow equilibrium in which very small densities of super-conducting ions (also molecular ions) and ionic supercurrents at cellular and other super-conducting space-time sheets dictate the corresponding densities at the atomic space-time sheets. Z^0 super-conductivity in principle allows to generalize the model also to the control of the densities of neural atoms and molecules at atomic space-time sheets.

This control mechanism need not be the only one. Magnetic flux tubes serving as colored braid strands connecting different bio-molecules in highly selective manner and phase transitions reducing or increasing $\hbar$ could explain the mysterious precision of bio-catalysis as how the prebiotic evolution has led to the known biology [L7]. Magnetic flux tubes could also act as Josephson junctions between widely separated structures.

2.1 Strange behavior of the intracellular water

The basic strange feature of cellular interior is related to its gelatinous nature and is in fact familiar for everyone. Although 80 percent of hamburger is water, it is extremely difficult to extract this water out. Ling [35] has demonstrated this at cellular level by using a centrifuge and cells for which cell membrane is cut open: centrifugal accelerations as high as 1000 g fail to induce the separation of the intracellular water.

The assumption that cytoplasm behaves like gel explains these findings. Egg is very familiar example of gel phase so that this proposal could have been made already by the pioneers. The dipolar nature of bio-molecules and induced polarization are basis prerequisites for the formation of gels. Ling raises the cohesion between water and protein molecules caused by electric dipole forces as a fundamental principle and calls this principle association-induction hypothesis [34]. This cohesion gives rise to liquid crystal [26] like structure of water implying among other things layered structures and internal electric fields orthogonal to the plane of the layers [34, 41, 42]. For instance, cell membranes can be understood as resulting from the self-organization of liquid crystals [I3]. The fundamental importance of electret nature of biomatter was also realized by Fröhlich [44] and led him to suggest that macroscopic quantum phases of electric dipoles might be possible. This concept, which is in central role in many theories of quantum consciousness, has not been established empirically.

2.2 Are channels and pumps really there?

Standard neurophysiology relies strongly on the concepts of what might be called hydro-electro-chemistry. The development of the theory has occurred through gradual improvements saving the existing theory.

The development began from the basic observation that cells are stable gelatinous entities not mixing with the surrounding water. This led to the hypothesis that cell membrane takes care that the contents of the cell do not mix with the cell exterior. It was however soon found that cell membrane allows some ions to flow through. The interaction between theory and experiment led gradually to the notions of ion channel and ion pump, which are still central for the standard paradigm of the cell [38]. Note that also 'electric pump' taking care that membrane potential is preserved, is needed.

These notions developed gradually during the period when cell was seen as a bag containing water and a mixture of various biochemicals. If cell biology would have started to develop during the latter half of this century and after the discovery of DNA, cell as a computer metaphor might have led to a quite different conceptualization for what happens in the vicinity of the cell membrane. Also the notion of liquid crystals [26] would have probably led to different ideas about how homeostasis between cell interior and exterior is realized [34, 41, 42].

For me it was quite a surprise to find that pump-channel paradigm is not at all so well-established as I had believed as an innocent and ignorant outsider. The first chapter of the book "Cells, Gels and the Engines of Life" of Gerald Pollack [33] provides a summary about the experimental paradoxes (the interested reader can find the first chapter of this book from web).

The standard theoretical picture about cell is based on the observation that cell exterior and interior are in a relative non-equilibrium. The measured concentrations of various atomic ions and organic molecules are in general different in the interior and exterior and cell membrane seems to behave like a semi-permeable membrane. There is also a very strong electric field over the cell membrane. In standard approach, which emerged around 1940, one can understand the situation by assuming that there are cell membrane pumps pumping ions from cell interior to exterior or vice versa and channels through which the ions can leak back. Quite a many candidates for proteins which seem to function like pump and channel proteins have been identified: even a pump protein for water [33]! This does not however prove that pumping and channeling is the main function

of these proteins or that they have anything to do with how ionic and molecular concentrations in the interior and exterior of the cell are determined. It could quite well be that pump and channel proteins are receptors involved with the transfer of information rather than charges and only effectively act as pumps and channels.

There are several serious objections of principle against the vision of cell as a bag of water containing a mixture of chemicals. Even worse, the hypothesis seems to be in conflict with experimental data.

2.2.1 Selectivity problem

Cell membrane is extremely selective and this leads to an inflation in the complexity of channels and pumps. The problem might be christened as a dog-door problem: the door for dog allows also cat go through it. Channels cannot be simple sieves: it is known that channels which let some ions through do not let much smaller ions through. There must be more complicated criteria than geometric size for whether the channel lets the ion go through. Quite generally, channels must be highly selective and this seems to require complicated information processing to decide which ion goes through and which not. As a consequence, the models for channels inflate in their complexity.

2.2.2 Inflation in the number of pumps and channels

Channels and pumps for atomic ions and channels and pumps for an astronomical number of organic molecules are needed. The first question is where to put all those channels and pumps? Of course, one could think that pumps and channels are constructed by the cell only when they are needed. But how does the cell know when a new pump is needed if the cell as never met the molecule in question: for instance, antibiotic or curare molecule?

To realize how weird the picture based on channels and pumps is, it is useful to imagine a hotel in which there is a door for every possible client letting only that client through but no one else. This strange hotel would have separate door for every five point five milliard humans. Alternatively, the building would be in a continual state of renovation, new doors being built and old being blocked.

There is however an TGD based objection against this slightly arrogant argument. In TGD framework cell is a self-organizing structure and it might be that there is some mechanism which forces the cell to produce these pumps and channels by self-organization. Perhaps the basic characteristic of quantum control in many-sheeted space-time is that it somehow forces this kind of miracles to occur.

2.2.3 Why pumping does not stop when metabolism stops?

One can also wonder how metabolism is able to provide the needed energy to this continual construction of pumps and channels and also do the pumping. For instance, sodium pump alone is estimated to take 45-50 per cent of the cell's metabolic energy supply. Ling has studied the viability of the notion of the ionic pump experimentally [34] by exposing cell to a cocktail of metabolic poisons and depriving it from oxygen: this should stop the metabolic activities of the cell and stop also the pumping. Rather remarkably, nothing happened to the concentration gradients! Presumably this is the case also for the membrane potential so that also the notion of metabolically driven electrostatic pumps seems to fail. Of course, some metabolism is needed to keep the equilibrium but the mechanism does not seem to be a molecular mechanism and somehow manages to use extremely small amount of metabolic energy.

2.2.4 How it is possible that ionic currents through silicon rubber membrane are similar to those through cell membrane?

A crucial verification of the channel concept was thought to come in the experiment of Neher and Sakmann [37] (which led to a Nobel prize). The ingenious experimental arrangement was following. A patch of membrane is sucked from the cell and remains stuck on the micropipet orifice. A steady voltage is applied over the patch of the membrane and the resulting current is measured. It was found that the current consists of discrete pulses in consistency with the assumption that a genuine quantum level current is in question. The observation was taken as a direct evidence for the postulate that the ionic currents through the cell membrane flow through ionic channels.

The later experiments of Fred Sachs [39] however yielded a complete surprise. Sachs found that when the patch of the cell membrane was replaced by a patch of silicon rubber, the discrete currents did not disappear: they remained essentially indistinguishable from cell membrane currents! Even more surprisingly, the silicon rubber membrane showed ion-selectivity features, which were essentially same as those of the cell membrane! Also the currents through synthetic polymer filters [40] were found to have essentially similar properties: as if ion selectivity, reversal potential, and ionic gating would not depend at all on the structure of the membrane and were more or less universal properties. Also experiments with pure lipid-layer membranes [47] containing no channel proteins demonstrated that the basic features – including step conductance changes, flickering, ion selectivity, and in-activation– characterized also cell membranes containing no ionic channels.

The in-escapable conclusion forced by these results seems to be that the existing 60-year old paradigm is somehow wrong. Ionic currents and the their properties seem to be universal and depend only on very weakly on the properties of the membrane.

2.3 Cytoplasm as gel

The solution to the above described anomalies proposed by Pollack is that cytoplasm is gel phase [33]. Pollack describes in detail various aspects of cytoplasm as a gel phase and here only short summary can be given.

1. Cytoplasm can be regarded as a network consisting of cross-linked negatively charged proteins. Water is condensed around the proteins to form structured water. If protein is hydrophilic, water self-organizes around it as a multilayered structure: the number of molecular layers can as high as 600 and the thickness of the layered structure is a considerable fraction of micrometer. If the protein is hydrophobic, water forms another structured phase known as clathrate water: in this case the number of hydrogen bonds between water atoms is large. These phases can be regarded as intermediate between ice and water. Also ordinary ions have this kind of layered structure around them. Chemical cross-links tend to be stable with heat, pH, and solvent composition whereas physical cross-links formed by intermolecular interactions are sensitive to environmental interactions and are of special interest from the point of view of phase transitions.

2. Pollack proposes that the formation of polymers takes place in an environment containing layered water for the simple reason that monomers cannot diffuse to the layered water so that the probability of association with the end of the growing polymer increases.

3. Cell interior is populated by micro-tubules, various filamentary structures, and the so called micro-trabecular matrix. Micro-trabecular network divides cell into a compartments in such a manner that the typical distance between two proteins in water is about 5 nm: this corresponds to the p-adic length scale $L(149)$, the thickness of the lipid layer of cell membrane. This is probably not an accident and the micro-trabecular network might be closely involved

with the highly folded network of intracellular membranes. There would be a layer of thickness of about 6 water molecules per given protein surface so that a dominating portion of intracellular water could be structured.

4. The layered water has several tell-tale signatures that have been observed in gels. It freezes at much lower temperature than ordinary water; various relaxation times are shorter since the energy transfer to the water lattice occurs faster than to non-structure water; the diffusion rates of particles into the structured water are much slower than to ordinary water by entropy argument; a simple geometric argument tells that the larger the size of the hydrated ion the lower the diffusion rate; strong gradients of ionic concentrations can form in gel phase as has been observed.

The identification of the cytoplasm as a gel has profound implications for the standard views about cell.

1. The original motivation for postulating semipermeable cell membrane, channels, and pumps was the need to hinder the diffusion of various ions between cell interior and exterior taking place if cytoplasm is ordinary water into which molecules are dissolved. If cytoplasm is in gel phase, cell membrane need not perform pumping and channeling anymore except perhaps in situations involving the formation of a local sol phase. This raises the question about the proper functions of the cell membrane.

2. It is possible to drill to cell membrane holes with size of order 1 μm without an appreciable effect on the functioning of the cell and also show that these holes remain as such for long periods of time [33]. It is also possible to splice cells into pieces continuing to function for days. That K^+ flux through cell membrane does not change when lipids are partially removed. These findings force to ask whether the assumption about the continuity of the cell membrane might be too strong [33]. Electron micrographs however demonstrate the presence of the bi-layered structure. What is intriguing that this structure is seen even in the absence of lipid layers. In TGD framework this paradoxical finding might be understood in terms of a presence of space-time sheets corresponding to p-adic length scales $L(k)$, $k = 149, 151$ as vacuum structures predicted also by TGD inspired model of high T_c super-conductivity [J1].

3. There is also the strange finding that water flux through cell membrane is much higher than the flux through isolate lipid bi-layer as if some unidentified channels were present. In TGD framework this might be seen as an evidence for the presence of (wormhole) magnetic flux tubes as carriers of water molecules.

4. The fundamental assumptions about ionic equilibrium must be reconsidered, and the Hodkin-Huxley model for the generation of nerve pulse becomes more or less obsolete. Indeed, it has been found that action potentials can be generated even in absence of Na^+ and K^+ ions playing a key role in Hodkin-Huxley model. Rather remarkably, the high concentration of K^+ ions and low concentration of Na_+ ions in cytoplasm could be understood on basis of gel property only. Also new view about cell (note membrane-!) potential emerges. The standard paradigm states that the resting potential is over the cell membrane. Potentials of same order of magnitude have been however seen in de-membraned cells (50 mV in slight excess of action potential and critical potential), colloidal suspensions, and gels which suggest that larger part of cell than mere cell membrane is involved with the generation of the action potential and one should thus speak of cell potential instead of membrane potential.

5. Pollack suggests that the phase transitions of the gel phase make possible to realize various functions at molecular and cellular level and represents empirical evidence for the phase transition like aspects assigned to these functions including sensitivity to various factors such as

pH, temperature, chemical environment, electromagnetic fields, mechanical forces, etc... and the threshold behavior [33]. Also the responses are typical for phase transitions in that they involve dramatic changes in volume, shape, di-electric constant, etc.. With these motivations Pollack discusses phase transition based models for contraction, motility, secretion, transport or molecules, organized flow of particles during cell division, cell locomotion, contraction of muscle, generation of action potentials, etc.. For instance, the transport of bio-molecules along micro-tubule could involve propagating gel-sol-gel phase transition meaning also propagating melting of the layered water around micro-tubule.

6. Divalent ions, such as Mg^{++} and Ca^{++} can act as cross links between negatively charged proteins binding them to form networks. Monovalent ions cannot do this. Peripheral cytoskeleton is this kind of network consisting of micro-tubules and actin molecules cross-linked - according to Pollack- by Ca^{++} ions. On the other hand, it is known that Mg^{++} (Ca^{++}) ions dominate in the cell interior (exterior) and that the presence of Ca^{++} ions in the cell exterior is crucial the for generation of nerve pulse. The influx of Na^+ ions having higher affinity to proteins can induce a phase transition to sol-like phase. Pollack suggests a model of nerve pulse based on this mechanism of gel-sol phase transition for peripheral cytoskeleton: this model does not actually explain why Ca^{++} ions in the exterior of axon are necessary.

2.4 TGD based vision inspired by the findings

The vision about dark matter and the model of nerve pulse formulated in terms of Josephson currents brings an additional perspective to the role of pumps and channels and allows to avoid harmony with the standard views about their role.

1. In long length scales visible matter forms roughly 5 per cent of the total amount of matter. In TGD Universe the dark matter would correspond to matter with large Planck constant including dark variants of ordinary elementary particles. In living matter situation could be the same and visible matter could form only a small part of the living matter. Dark matter would be however visible in the sense that it would interact with visible matter via classical electromagnetic fields and photon exchanges with photons suffering Planck constant changing phase transition. Hence one can consider the possibility that most of the biologically important ions and perhaps even molecules reside at the magnetic flux quanta in large $\hbar$ phase.

2. Bosonic ions could form Bose-Einstein condensates at the flux tubes in which case supra currents flowing without any dissipation would be possible. The model for high T_c superconductivity suggests that only electronic and protonic super-conductivity are possible at room temperature. If so, Cooper pairs of fermionic ions are excluded. New nuclear physics predicted by TGD could however come in rescue here. The TGD based model for atomic nucleus assumes that nuclei are strings of nucleons connected by color bonds having quark and antiquark at their ends. Also charged color bonds are possible and this means the existence of nuclei with anomalous charge. This makes possible bosonic variants of fermionic ions with different mass number and it would be interesting to check whether biological important ions like Na^+, Cl^-, and K^+ might actually correspond to this kind of exotic ions.

This leads to the following TGD inspired vision about cell as a gel.

1. DNA as tqc hypothesis and cell membrane as sensory receptor provide possible candidates for the actual functions of the cell membrane and ionic channels and pumps could act as kind of receptors. That standard physics is able to to describe gel phase is of course a mere belief and (wormhole) magnetic flux tubes connecting various molecules (DNA, RNA, aminoacids,

biologically important ions) would be "new physics" cross-links could explain the strong correlations between distant molecules of the gel phase.

2. Dark ionic currents are quantal currents. If the dark ions flow along magnetic or wormhole magnetic flux tubes connecting cell interior and exterior, their currents through cell membrane would be same as through an artificial membrane.

3. Pumps and channels could serve the role of sensory receptors by allowing to take samples about chemical environment. One cannot exclude the possibility that proteins act as pumps and channels in sol phase if magnetic flux tubes are absent in this phase since also in TGD Universe homeostasis and its control at the level of visible matter in sol phase might requires them. The metabolic energy needed for this purpose would be however dramatically smaller and a reliable estimate for this would allow an estimate of the portion of dark matter in living systems.

4. Quantum criticality suggests that the phase transitions for the gel phase are induced by quantum phase transitions changing the value of Planck constant for magnetic flux tubes and inducing the change of the length of the flux tube. Macroscopic quantum coherence would explain the observed co-operativity aspect of the phase transitions. Concerning locomotion and transport mountain climbing using pickaxe and rope inspires a guess for a general mechanism. For instance, a packet of molecules moving along actin molecule or a molecule carrying a cargo along micro-tubule could repeat a simple basic step in which a magnetic flux tube with large $\hbar$ is shot along the direction of the electric field along micro-tubule and stuck to a rachet followed by a phase transition reducing the value of $\hbar$ and shortening the flux tube and forcing the cargo to move forward. The metabolic energy might be provided by the micro-tubule rather than molecular motor.

5. The reconnection of flux tubes would be a second phase transition of this kind. This phase transition could lead from a phase in phase proteins are unfolded with flux tubes connecting aminoacids to water molecules and thus possessing a large volume of layered water around them to a phase in which they become folded and flux tubes connect aminoacids to each other in the interior of protein. The phase transition could be associated with the contraction of connecting filaments of muscle cell. The phase transitions are also seen in "artificial protein" gels used for drug delivery applications, and are built from polymers arranged in alpha helices, beta sheets and common protein motifs [33]. If wormhole magnetic flux are taken are taken as a basic prerequisite of life, one must ask whether these "artificial proteins" represent artificial life.

6. The fact that cytoskeleton rather than only cell membrane is involved with the generation of action potential conforms with the idea that nerve pulse propagating along axon involves also axonal micro-tubules and that Josephson currents between axon and micro-tubules are involved in the process.

7. Di-valent ions (Ca^{++} ions according to Pollack) serve as cross links in the peripheral cytoskeleton. The influx of monovalent ions from the exterior of axon induces gel-sol phase transition replacing di-valent ions with monovalent ions. One can consider two models.

   i) The minimal assumption is that this phase transition is induced $\hbar$ increasing phase transition the flow of the monovalent ions like Na^+ from the cell exterior along the magnetic flux tubes connecting axonal interior and interior. Suppose that in the original situation the flux tubes end to axonal membrane (this is not the only possibility, they could also end to Ca^{++} ions). The flux tubes extending to the axonal exterior could result by $\hbar$ increasing phase transition increasing the length of the flux tubes connecting peripheral cytoskeleton to the

axonal membrane so that they extend to the exterior of axon. This option is rather elegant since gel-sol phase transition itself can be understood in terms of "standard chemistry". In this model the very slow diffusion rate of the ions to gel phase would have explanation in terms of new physics involving dark matter and (wormhole) magnetic flux tubes.

ii) One can consider also an option in which divalent ions such as Ca^{++} or Mg^{++} are connected by two flux tubes to amino-acids of two negatively charged proteins whereas monovalent biological ions like Na^+ would have single flux tube of this kind and could not act as cross links. In the phase transitions removing the cross links the replacement of divalent ion with two monovalent positively charged ions would take place. If one believes in standard chemistry, Na^+ ions would flow in automatically. First the increase of Planck constant would induce the lengthening of the magnetic flux tubes and thus the expansion of the gel phase making possible the influx of monovalent ions. If Na^+ ions are dark, flux tubes connecting peripheral cytoskeleton to the axonal exterior are required and the mechanism of option i) is also needed.

8. The mechanisms i) and ii) could be fused to a single one. The hint comes from the presence of Ca^{++} ions in the exterior of axon is necessary for the generation of action potential. The simplest possibility is that the flux tubes connecting proteins to intracellular Ca^{++} cross links in gel phase connects them after the length increasing phase transition to extracellular Ca^{++} ions and Na^+ ions flow along these flux tubes.

9. The increase of the Planck constant would induce the expansion of the peripheral cytoskeleton making possible the inflow of Na^+ ions, and divalent ions binding negatively charged actin molecules to a network would be replaced with inflowing Na^+ ions. After this a reverse phase transition would occur. Both phase transitions could be induced by a quantal control signal (Josephson current) inducing quantum criticality and a change of Planck constant.

10. A propagating Ca^{++} wave inducing the gel-sol-gel phase transition of peripheral cytoskeleton would accompany nerve pulse. Quite generally, Ca^{++} waves are known to play a fundamental role in living matter as kind of biological rhythms. Irrespective of whether one believes option i) or ii), this might relate to the cross-linking by flux tubes and gel-sol-gel phase transitions induce by phase transitions increasing Planck constant temporarily. The velocities and oscillation periods of Ca^{++} waves vary in an extremely wide range: this can be understood if the flux tubes involved correspond to a very wide spectrum of Planck constant.

To sum up, the strange discoveries about the behavior of cell membrane provide direct experimental evidence for the presence of dark matter in living systems, for the prediction that it interacts with ordinary matter via classical electromagnetic fields, and for the assumption that it does not dissipate appreciably and could therefore have large value of $\hbar$ and form macroscopic quantum phases.

3 TGD based model for the generation of nerve pulse and EEG

The general vision about living system as a conscious hologram and the view about how "topological light rays" (massless extremals, MEs) serve as remote entanglers and induce self-organization via the leakage of ionic currents between various space-time sheets implies that several space-time sheet pairs are involved with the bio-control. Perhaps the most radical deviation from the standard neuroscience thinking came with the realization that in TGD Universe every physical system has also magnetic/field body of size much larger than the material body and that material bodies can

be seen as motor and sensor organs of the personal magnetic body. This counter intuitive conclusion is unavoidable if one accepts many-sheeted macroscopic quantum coherence, Uncertainty Principle and topological field quantization. p-Adic physics as physics of intention and cognition provides an additional support for this view: the smaller the space-time sheet is p-adically, the larger it is in the real sense so that cognition and intentionality are predicted to be astrophysical phenomena and evolve from long to short length and time scales just as it indeed occurs when motor activity is learned.

The TGD based view about dark matter hierarchy involving a hierarchy of values of Planck constant provides a justification for this picture. Dark matter hierarchy corresponds to the hierarchy of moments of consciousness with increasingly long duration with respect to geometric time and defines a hierarchy of conscious entities and reflective levels of consciousness.

Dark matter hierarchy provides a mechanism for the formation of macroscopic and macrotemporal quantum phases in all length scales. The earlier assumption about thermal isolation of space-time sheets corresponding to different p-adic length scales can be given up and thermal stability condition becomes an additional strong constraint allowing to eliminate various options very effectively. Since cyclotron energies scale like $\hbar$, thermal stability is possible to achieve for them.

In this section TGD based model of nerve pulse and EEG inspired by the soliton model of Danish researchers and the model of Pollack is discussed. Also a model for the action of anesthetics is proposed.

3.1 Soliton model of nerve pulse

Let us first briefly summarize soliton model of nerve pulse proposed by Danish researchers [67, 68, 69, 70].

1. The temperature of the axon is slightly above the critical temperature T_c for the phase transition leading from crystal like state of the lipid layers to a liquid crystal state. Near criticality the elastic constants and heat capacity of the membrane vary strongly and have maxima at criticality so that also sound velocity varies strongly near criticality. Also the relaxation times are long. There is also dispersion present meaning that the frequency of sound wave depends nonlinearly on wave vector. Non-linearity and dispersion are prerequisites for the presence of solitons which by definition do not dissipate energy.

2. Variations of temperature, volume, area, and thickness and also other mechanical effects are known to accompany nerve pulse propagation. It is also known that the heat density and temperature of the cell membrane increases slightly first and is then reduced. This suggests adiabaticity in average sense. These findings motivate the assumption that nerve pulse actually corresponds to acoustic soliton [68, 69].

3. Soliton model reproduces correctly the velocity of nerve pulse inside myelin sheaths but it is not clear to me how well the much lower conduction velocity in non-myelin sheathed regions is reproduced. It is not clear how the lower values of the conduction velocity and its proportionality to the axonal radius in non-myelinated regions can be understood. Intuitively it however seems clear that the lower velocity is due to the feedback from the interaction of ions with the region exterior to cell membrane. In the case of myelin sheaths the conduction of nerve pulse is usually believed to take place via saltation [71]: the depolarization induced at Ranvier node is believed to be enough to take the membrane potential below critical value in the next node so that nerve pulse hops between the nodes. Insulation would improve the insulation and make this process possible. The reversible heat transfer process is however known to be present also in the myelinated portions of axon so that there must be a pulse propagating also in these regions [69]. It is not clear how the myelin sheet can increase the

velocity in the soliton model but the reduction of the feedback inducing friction suggests itself.

4. Soliton property predicts adiabaticity. Ordinary ionic currents however dissipate so that adiabaticity assumption is questionable in standard physics context. The model does not predict the growth of entropy followed by its reduction. This behavior is consistent with adiabaticity in a time resolution of order millisecond.

5. The estimate for the capacitor energy density during the nerve pulse is considerably smaller than the energy density is many times magnitude smaller than that of the acoustic wave. This might allow to demonstrate that Hodgkin-Huxley model is not a complete description of the situation.

6. Authors notice [68, 69] that the shapes curves representing solitonic energy density and the capacitor energy density as a function of time are essentially identical. Same applies to the experimentally deduced heat change release curve and capacitor energy density for garfish axon. Also heat release and the deviation of the membrane potential from its resting value are in exact phase. These similarities could reflect a control signal responsible for the nerve pulse originating somewhere else, perhaps at micro-tubules. This could explain why secondary nerve pulse is not generated immediately after the first one although the temperature is slightly lower after the pulse than before it. This could of course be also due to the exhaustion of the metabolic resources.

3.2 TGD based model of nerve pulse

The model of nerve pulse described below can be motivated by the observed adiabaticity of the nerve pulse and by the strange findings about ionic currents associated with the cell membrane and by the model of Danish researchers for the nerve pulse [66, 67, 68, 69]. The model involves also a fusion of various ideas of earlier models. In particular, Josephson currents and solitons are in a key role in the model but with the necessary flexibility brought in by the hierarchy of Planck constants. The model of nerve pulse by Pollack [33] discussed at the end of previous section allows to understand the behavior of ionic currents quantitatively.

3.2.1 Consistency with the absence of dissipative currents through the axonal membrane

The basic inputs of the TGD based model are following.

1. The presence of acoustic soliton or density pulse proposed by Danish researchers [69] looks plausible but a a more fundamental quantum control mechanism inducing the acoustic soliton cannot be excluded. Among other things this should explain why acoustic solitons propagate always in the same direction. In particular, one can consider a soliton like excitation (say breather for Sine-Gordon equation) associated with the electronic or ionic Josephson currents running along magnetic flux tubes. The strange effects associated with the ionic currents through the cell membrane suggest quite generally that at least weak ionic currents through normal cell membrane are non-dissipative quantal currents. The adiabaticity of the nerve pulse suggests that also strong ionic currents are quantal.

2. Strong ionic currents generating nerve pulse through axonal membrane are absent in the resting state. The naive explanation is simple: the life time of the magnetic flux tubes connecting the axonal interior to the exterior is short or the flux tubes are altogether absent. The observation that Josephson currents in constant voltage are automatically periodic suggests a less naive explanation allowing the flux tubes to be present all the time. The presence

of ionic Josephson currents predicts a small amplitude oscillation of membrane potential for which 1 kHz synchronous oscillation is a natural identification. Josephson oscillation correspond naturally to propagating soliton sequences for Sine-Gordon equation. The dynamics of the simplest modes is equivalent to the rotational motion of gravitational pendulum: the oscillation of membrane potential corresponds to the variation of $d\Phi/dt \propto V$. Note that if axon is above the melting temperature, the lipid layer is in gel phase and fluid motion is impossible. The surface density of lipids is dramatically reduced at criticality so that lipid layers behave like fluids [69]. This means that tqc is not possible by the braiding of lipids.

3. Nerve pulse is generated when the magnitude of the negative membrane potential is reduced below the critical value. Generation of the nerve pulse is like a kick to a rotating gravitational pendulum changing the sign of $\Omega = d\Phi/dt$ so that rotational motion is transformed to oscillatory motion lasting for about the period of rotation. An opposite but slightly stronger kick must reduce the situation to the original one but with a slightly higher value of Ω. These kicks could correspond to voltage pulse between micro-tubules and inner lipid layer of cell membrane induced by the addition of small positive (negative) charge on lipid layer. This pulse would induce electronic DC Josephson current inducing the kick and thus reducing V. The exchange of scaled variants of W bosons (assignable to W MEs) could mediate the transfer of charge through the cell membrane and reduce the membrane potential below the critical value but one can consider also other mechanisms.

4. The conservative option would be that ordinary ionic currents take care of the rest and Hogkin-Huxley model applies. This was assumed in the earliest model in which soliton sequence for Josephson current was assumed to induce nerve pulse sequence: in the recent model this assumption does not make sense. The findings of Danish researchers do not however support the conservative option [69]. Nerve pulse could be due to dark ionic (possibly supra -) currents with large $\hbar$ with a low dissipation rate. Their flow would be made possible by the presence of magnetic flux tubes connecting cell interior and exterior.

3.2.2 The relationship with the model of Pollack

In the model of Pollack [33] for the action potential gel-sol-gel phase transition for the peripheral cytoskeleton accompanies the generation of the action potential. The model allows to understand reasonably well the behavior and the physical role of the ionic currents and explains various anomalies. Using pendulum analogy, the kick to the rotating pendulum representing Josephson junction would force it to an oscillatory motion inducing a gel-sol-gel phase transition propagating along the peripheral cytoskeleton.

The challenge is to understand how quantum criticality making possible the phase transition is induced.

1. The primary Josephson currents from the micro-tubuli to the axonal membrane would reduce the magnitude of the cell potential below the critical value (slowing down of the pendulum rotation). This should somehow take the peripheral cytoskeleton near to quantum criticality and induce the increase of Planck constant for the flux tubes connecting peripheral cytoskeleton to the axonal membrane and increasing their length so that they would extend to axonal exterior. This would make possible the flow of monovalent dark ions (say Na^+) from the axonal exterior replacing Ca^{++} acting as cross links between negatively charged proteins and in this manner induce gel-sol phase transition. The reverse phase transition would reduce Planck constant. If ionic currents are non-dissipative they flow back automatically much like oscillating Josephson currents.

2. There are two forms of quantum criticality corresponding to critical sub-manifolds $M^2 \times CP_2$ and $M^4 \times S^2$, where $M^2 \subset M^4$ has interpretation as plane of non-physical polarizations and

$S^2 \subset CP_2$ is a homologically trivial geodesic sphere of CP_2 with vanishing induced Kähler form (see the Appendix of [L7]). The latter kind of quantum criticality corresponds to very weak induced Kähler fields and thus to almost vacuum extremals. Given electromagnetic field can be imbedded as a 4-surface in many manners: as a vacuum extremal, as a surface maximizing Kähler electric energy, or something between them.

3. Quantum criticality suggests that em fields in the cell interior corresponds to nearly vanishing induced Kähler fields and that in the resting state the em fields at cell membrane and peripheral cytoskeleton correspond to strong Kähler fields. The magnitude of the cell potential in the absence of the membrane is about .05 V and slightly below the magnitude of the critical potential [33]. Hence the reduction of the magnitude of the em (-or more precisely- Kähler-) voltage between the inner boundary of the peripheral cytoskeleton and cell exterior to a small enough value could induce quantum criticality making $\hbar$ increasing phase transition for the magnetic flux tubes connecting peripheral cytoskeleton to the axonal membrane possible. This framework also allows to understand the paradoxical fact that a reduction of the magnitude of the cell potential induces the action potential rather than its increase as the naive idea about di-electric breakdown would suggest.

4. The energy of the Josephson photon associated with cell membrane Josephson junction is about .05 eV at criticality for the generation of action potential. This is not too far from the value of the metabolic energy quantum liberated in the dropping of proton Cooper pair from $k = 139$ atomic space-time sheet or of electron Cooper pair from $k = 151$ cell membrane space-time sheet to a much larger space-time sheet. This leads to the idea that phase conjugate IR photons of Josephson radiation couple resonantly to the gel defined by the peripheral cytoskeleton and induce fast dropping of protons to larger space-time sheets and that this in turn induces the increase of Planck constant for magnetic flux tubes inducing gel-to-sol phase transition. This idea has been discussed already earlier and will reconsidered in the section where the relationship of the model with microtubular level is discussed.

5. A comment relating this picture to DNA as tqc model is in order. The basic difference between TGD and standard model is that color rotations leave invariant the induced Kähler field but affect electro-weak gauge fields. In particular, color rotations change the intensity of em field by transforming em and Z^0 fluxes to each other. In the recent case color rotation cannot obviously reduce the value of the electric field. The most elegant variant of the model of DNA as tqc replaces qubit with qutrit (true/false/undefined) presented as color triplet of quarks associated with the (wormhole) magnetic flux tubes connecting nucleotides with lipids [L7]. Hence the color rotations representing basic 1-gates would not affect induced Kähler fields and cannot induce phase transitions although they would affect cell potential. For 2-gate represented by the basic braiding operation permuting the ends of the neighboring strands the situation is different. Quantum criticality would make possible the generation of braiding by taking cell membrane to liquid state. The discussion about the effects of anesthetics in the sequel forces however to conclude that in the liquid crystal state action potentials are not possible. Propagating action potentials could however represent tqc programs as time-like braidings if it is microtubular surface that suffer gel-sol-gel transition during the nerve pulse.

3.2.3 What the replacement of Ohmic ionic currents with quantal currents means?

Before the replacement of Hodgkin-Huxley model with a genuinely quantal model can be taken seriously, one must answer many difficult questions which also Hodgkin and Huxley must have faced as they developed their own model.

1. Questions and answers

Q: In the resting state membrane potential is negative and cell has a negative net charge. What stabilizes the cell against the leakage of the negative charge if pumps and channels are not responsible for this?

A: The findings about the strange behavior of cell membrane inspire TGD based answer. Cell membrane space-time sheet is its own quantum world and the flow of ions occurs only in the presence of magnetic flux tubes connecting it to the external world. These currents a however oscillatory Josephson currents if dissipation is absent. Hence there is no need to cut completely the connections to the external world.

Q: How the resting state can result spontaneously if pumps are absent?

A: If ionic currents are Josephson currents, they are automatically oscillating and the return to the original state is guaranteed. The flux tubes carrying the ionic currents will be assumed to connect axonal micro-tubules to the space-time sheet of the cell interior. Consider first the most obvious objections.

1. Dark ions cannot transform to ordinary ones in the exterior of the cell membrane. This might indeed kill the model.

2. The second objection is that all biologically important ions are not bosons and the model for high T_c super-conductor in its recent form allows only electronic and protonic Cooper pairs at room temperature [J1]. TGD based nuclear physics however predicts the possibility of exotic nuclei for which one or more color bonds connecting nucleons to the nuclear string are charged. These exotic nuclei with electronic states identical to those of genuine ions could save the situation.

The table below describes how cyclotron frequencies for $B = .2$ Gauss of the most important ions are modified in the simplest replacements with exotic ions. For instance, the notation Mg_-^{++} tells that there is double electronic ionization and electron shell of Argon as usual but that one color bond is negatively charged.

Ion	f_c/Hz	$Pseudo-ion$	f_c/Hz
$^{23}Na^+$	13.1	$^{19}Ne_+$	15.7
$^{23}Na^+$	13.1	$^{24}Mg_-^{++}$	12.5
$^{39}K^+$	7.7	$^{40}A_+$	7.5
$^{39}K^+$	7.7	$^{40}Ca_-^{++}$	7.5
$^{35}Cl^-$	8.6	$^{40}A_-$	7.5

(1)

$f_c(K+)$ and $f_c(Cl^-)$ are replaced with the frequency 7.5 Hz and one can do only using the cyclotron frequencies $f(Ca^{++})/2 = 7.5$ Hz, $f_c(Mg^{++}) = 12.5$ Hz, and $f(Ca^{++}) = 15$ Hz. The nominal values of the lowest Schumann frequencies are 7.8 Hz and 14.3 Hz. All ions with relevance for nerve pulse and EEG could be bosonic ions or bosonic pseudo-ions. I do not know how well the needed ionization mechanisms are understood in the standard framework.

For small oscillations the maximal charge transfer ΔQ generated by an oscillating ionic Josephson current during the cycle is proportional to $\hbar/f_J \propto \hbar^2$ and $\hbar/\Omega \propto \hbar$ for solitonic situation. ΔQ is very small for the ordinary value of $\hbar$: also the oscillation period is very small. For large values of $\hbar$ situation changes and large maximal ion transfers are possible. An $\hbar$ increasing phase transition could be involved with the generation of the nerve pulse. Quantum criticality during nerve pulse generation indeed suggest the presence of flux tubes with varying values of $\hbar$. The lifetimes of the connected flux tubes could be proportional to $\hbar$ at criticality. A fractal hierarchy

of pulses and EEG like oscillations of the membrane potential corresponding to various values of $\hbar$ is suggestive.

Q: Can one make this more quantitative?

A: One can construct a model based on Sine-Gordon wave equation for the phase difference Φ between the superconductors connected by Josephson junction sequences defined by magnetic flux tubes and idealizable as a continuous Josephson junction.

1. For a Josephson junction idealizable as a hollow cylinder with radius R and thickness d the expression of the Josephson current reads as

$$J = J_0 sin(Ze \int V dt/\hbar) \ .$$

J_0 is in case of cell membrane given by

$$J_0 = \frac{Ze2\pi dR}{\Lambda^2}\frac{\hbar}{m} \ ,$$

where R and d would be now the radius and thickness of the axon, Λ is the magnetic peneration length, and m is the mass of the charge carrier. Although this expression does not hold true as such when Josephson junctions are replaced by magnetic flux tubes connecting micro-tubules and axon, one can can safely make some qualitative conclusions. The amplitude of the Josephson current increases with $\hbar$. For electron the value of the amplitude is by a factor $x \simeq Am_p/m_e \simeq 2^{11}A$ larger than for ion with a mass number A. This gives for electron Cooper pairs a unique role as an initiator of the nerve pulse. Note that the amplitudes of the Josephson currents of electron and ions are quite near to each other if one has $\hbar(ion) = 2^{11}A\hbar e$: this might explain why the powers of 2^{11} for $\hbar$ seem to be favored.

2. Electronic Josephson current dominates and makes it ideal for the generation of nerve pulse (kick to gravitational pendulum). This is possible if the net amount of electronic charge is so small that it flows out during the generation of flux tubes. For ions this need not occur even if ion densities are of same order of magnitude. Constant voltage V creates an oscillating current and no catastrophic leakage takes place and the resting state results automatically. The ionic Josephson currents assignable to the magnetic flux tubes connecting micro-tubules through the cell membrane to the external world could be responsible for the nerve pulse.

3. The mechanical analog for Sine-Gordon system [19] assignable to Josephson junction is rotating pendulum but one must be cautious in applying this analogy. There are two options concerning the modeling of the situation.

   i) Membrane potential represents an external voltage $V(t)$ and one has $\Phi_i = Z_i e \int V dt/\hbar$, where Φ is the phase difference between Bose-Einstein condensates.

   ii) System is autonomous and membrane potential $V(t) = \hbar(d\Phi_i/dt)/Z_i e$ is completely determined by the dynamics of any phase Φ_i. This option is highly predictive and discussed in the sequel.

4. The analogy with gravitational pendulum allows to identify the phase angle Φ as the counterpart of angle Θ characterizing angular position of mathematical pendulum (note that this analogy can be misleading since it implicitly brings in 3-D thinking).

   i) In this picture rotating pendulum corresponds to a soliton sequence containing infinite number of solitons: both stationary and moving soliton sequences are obtained. The sign

of $\Omega = d\Phi/dt$ is fixed and approximately constant for large values of Ω. Resting potential could correspond to this kind of situation and $\Omega \simeq 2\pi$ kHz is suggested by kHz synchrony. A mechanism of this synchrony will be discussed below. For large values of $\hbar$ even values of Ω in EEG range could correspond to membrane potential. For large values of Ω one as $V \simeq \hbar\Omega_i/Z_i e$. If also EEG rhythms correspond to Ω they must correspond to different values of $\hbar$ and $f \propto 1/\hbar$ would hold true. Changes in the dominating EEG rhythm (40 Hz, 10 Hz, 5 Hz,..) could correspond to phase transitions changing $\hbar$ to given value for a large number of axons. The maximal charge transfer during single period is proportional to $\Delta Q \propto 1/\Omega$.

ii) Hyperpolarization/polarization would mean fastening/slowing down of the pendulum rotation and slowing down would make the system unstable. Near criticality against the generation of nerve pulse would mean that pendulum is rotating rather slowly ($\Omega \ll f_J$) so that a small kick can transform rotation to oscillation. The sign of $V \propto d\Phi/dt$ would change and large amplitude oscillatory motion would result for single period only after which a kick in opposite direction would lead back to the resting state. Membrane potential varies between the resting potential $V_0 = -75$ V and $V_1 = +40$ V during nerve pulse: $V_1 > |V_0|$ would have killed the model. Note that $V_1 = 40$ V is rather near to the critical potential about $V_1 = 50$ V: ideally these potentials should be identical.

iii) The so called breathers -both stationary and moving- correspond to soliton-antisoliton bound state (see the visualization in [19]). Breathers could be identified as large amplitude oscillations around $\Phi = 0$ ground state. Physical intuition suggests that breathers are possible also for a ground state corresponding to a rotating pendulum (representing moving or stationary waves). They would correspond to kicking of one pendulum in a sequence of pendulums along z-axis rotating in phase at the initial moment. The kick could correspond to a genuine external perturbation generated by a pair electronic supra current pulses of opposite sign giving constant velocity increments $\Delta\Omega$ initiating and halting the nerve pulse just like they would do in the case of tqc but in opposite time order. If the background corresponds to a propagating EEG wave, also nerve pulse is expected to propagate with same velocity. The propagation direction of EEG wave would also explain why nerve pulses propagate only in single direction.

5. For the ordinary value of $\hbar$, the frequency Ω of the Josephson current corresponds to that assignable to energy .07 eV being around $f = 1.6 \times 10^{13}$ Hz and quite high. For $x \equiv \hbar/\hbar_0 = 2^{44}$ the frequency would be near to cyclotron frequency of about 1 Hz assignable to DNA strands. For $x = 3 \times 2^{3\times 13}$ f would be near to the fundamental 10 Hz frequency which is secondary p-adic time scale associated with electron and correspond to the temporal duration of negative energy space-time sheet assignable to electron. For $x = 3 \times 2^{3\times 11}$ one would obtain a 640 Hz frequency which corresponds to the time scale of nerve pulse. It seems clear that the original hypothesis that only powers of 2^{11} define the spectrum of Planck constant is too restrictive. The requirement that cyclotron frequencies and Josephson frequencies are proportional to each other for small oscillations would guarantee resonant behavior for common strength of the magnetic field would give $\hbar \propto A$. This would require that each ion species lives at its own flux tubes.

Q: What instabilizes the axon? Why the reduction rather than increase of the magnitude of the membrane potential induces the instability? Why the reduction of the resting potential below the critical value induces nerve pulse?

A: Large enough voltage pulse between micro-tubules and membrane could generate electronic DC supra current. The introduction of a small amount of positive charge to the inner lipid layer and staying there for some time would generate the voltage pulse between micro-tubules and lipid layer so that DC electronic supra current would be induced, and induce the reduction $\Delta V \simeq .02$

eV of the magnitude of the membrane potential. A similar introduction of negative charge would induce hyperpolarization and the direction of the current would be opposite if it is generated at all. The mechanism generating the small positive charge to the inner lipid layer could be based on the exchange of exotic W bosons between pairs of exotic nuclei at opposite sides of the cell membrane so that the negative charge of the inner lipid layer would be reduced.

Q: Can one understand the observed radial force, the increase of the radius of axons and the reduction of its thickness, and heating followed by cooling?

A: The observed outward force acting on a test system might be due to the ionic Josephson currents to which the test system responds. During the second half of the pulse the sign of the ionic force is predicted to change. The pressure caused by the electronic Josephson current pulse might relate to the increase of the radius of the axonal membrane and with the reduction of its thickness as well as the slight increase of its temperature as being due to the electrons which heat the lipid layer as they collide with it. The ions return at the second half of the pulse and could transfer the heat away by convection.

1. This hypothesis gives the estimate for the force f per unit area as

$$\begin{aligned} f_{2e}(t) &= \frac{dn(lipid)}{da} \times \frac{J(t)}{2e} \times \hbar k \\ &= \frac{dn}{da} \times U \times \frac{\hbar^2 k}{2m_e c} \times sin(\omega_J(2e)t) \ , \\ U &= \frac{2\pi A}{\Lambda^2} \ . \end{aligned} \tag{2}$$

   The parameter A corresponds to the parameter dR in the case that Josephson junctions have the thickness of axonal membrane, and is not relevant for order of magnitude estimate. R corresponds to the distance between micro-tubules and cell exterior space-time sheet to which flux tubes end. $dn(lipid)/da$ is the 2-D density Josephson junctions equal to the density of lipids.

   $k \simeq 2\pi/R$ is the wave vector of electron Cooper pair at the magnetic flux tube. The 3-momentum of electron is enormous for the proposed value of $\hbar$, and the only possible interpretation is that the four-momentum of electron is virtual and space-like and corresponds to exchange of space-like virtual photon describing Coulomb interaction with lipid layer.

   Λ^2 satisfies in the first approximation the formula

$$\Lambda^{-2} = \frac{4\pi e^2 n_e}{m_e} + \sum_I \frac{4\pi e^2 n_I}{A m_I} = \alpha_{em} 16\pi^2 \times [\frac{\hbar_0 n_e}{m_e} + \sum_I \frac{\hbar_0 n_I}{A_I m_I}] \ . \tag{3}$$

   Note that there is no real dependence on $\hbar$. Above critical voltage electrons could dominate in the expression but during nerve pulse ions should give the dominating contributions. U cannot be too far from unity.

2. From this one can integrate the total momentum of Cooper pairs transferred to the lipid layer before the flux tubes fuse together if one knows the value of time t when this happens. $F \propto \hbar^2/m_e^2$ proportionality implies that for the required large value of $\hbar/\hbar_0 \simeq 3 \times 2^{33}$ the force is by a factor 6×10^{20} stronger than for $\hbar_0$.

3. The force caused by ionic Josephson currents on piston is given by

$$f(t) \;=\; \sum_I \frac{2me}{m_I}\frac{2}{Z_I} \times f_{2e}(\frac{Z_I}{2}\frac{\Omega}{\omega_J}t) \;\; . \tag{4}$$

The comparison with the observed force gives estimate for the value of magnetic penetration length and thus density of electrons at the flux tube.

4. According to [69] in one particular experiment the force on piston of area $S = .01$ cm^2 at the maximum of voltage ($t = 2\pi/\Omega$) is $F = 2$ nN. This gives a killer test for the model. One obtains an estimate for the parameter $U = \frac{\Lambda^2}{2\pi A}$ as

$$U \;\equiv\; \frac{\Lambda^2}{2\pi A} = \frac{dn}{da}S \times \frac{\hbar^2 k}{m_p c F} \times \sum_I \frac{2}{A_I Z_I} \;\; . \tag{5}$$

The value of U should not deviate too much from unity. One can use the estimates

$$\tfrac{\hbar}{\hbar_0} = 3 \times 2^{33} \;\; , \quad k = \tfrac{2\pi}{R} \;\; .$$

Note that the experimental arrangement forces to use this value of k. The actual value in normal situation could be smaller and depends on the distance of the boundary of cell exterior space-time sheet on micro-tubules. Using the values $d = 10$ nm and $R = 5$ μm this gives

$$\begin{aligned} U \;&\simeq\; \sum_I \frac{2}{A_I Z_I} \times X \;\; , \\ X \;&=\; 9 \times 2^{66} \times \frac{\hbar_0^2 2\pi}{m_p c F R} \times \frac{S}{S(lipid)} \;\; . \end{aligned} \tag{6}$$

The factor $X = .9267$ is of order unity! Taking into account that $\hbar/\hbar_0$ is enormously large number it is difficult to believe that the result could be mere accident. Hence U does not deviate too much from unity and there are good hopes that the model works.

For $n_I = x_I/a^3$, $a = 10^{-10}$ m, and $A = dR$ one obtains a direct estimate which combined with above estimate gives two conditions which should be consistent with each other:

$$\begin{aligned} U &= 76.1 \times \textstyle\sum_I \frac{x_I}{A_I} \;\; , \\ U &= .93 \times \textstyle\sum_I \frac{2}{A_I Z_I} \;\; . \end{aligned} \tag{7}$$

These estimates are consistent for $x_I \sim 10^{-2}$, which makes sense.

Q: Where the primary wave propagates: along axon or along micro-tubules?

A: This question need not make sense if micro-tubules and axon are connected by magnetic flux tubes to form single quantum coherent system. That axonal micro-tubules have constant electric field which is always in same direction could explain why the background soliton sequences and

nerve pulses propagate always in the same direction and suggests that the primary wave propagates along micro-tubules. On the other hand, if W exchange between cell exterior and exterior reduces the negative charge of the inner lipid layer then axon could be seen as initiator. This could induce conformational or gel-sol phase transition propagating along micro-tubule and inducing the pair of voltage pulses in turn inducing the fusion of flux tubes at cell membrane which in turn would induce criticality of the axonal membrane. For this option axonal soliton would be a shadow of the micro-tubular soliton rather than completely independent dynamical process.

Q: How nerve pulse velocities are determined?

A: At first glance it seems nerve pulse velocity v could be determined by boundary conditions guaranteing synchronization of neuronal activity rather than by dissipation as in Hodgkin-Huxley model. As a matter fact, dissipation turns out to affect also v just because it is determined by boundary conditions!

1. Hodgkin-Huxley model would suggest that nerve pulse velocity is dictated by frictional effects as an analog of a drift velocity. The rough order of magnitude estimates for the velocities of conformational waves along micro-tubuli are consistent with the velocities of nerve pulses. The proportionality $v \propto d$ of nerve pulse velocity to nerve axonal radius might be understood as resulting on the dependence on the length of flux tubes connecting axon and micro-tubules and mediating a frictional feedback interaction from axon. Feedback would be naturally reduced as d increases. Feedback interaction could explain also the sensitivity of the thermal parameters of the axonal membrane to the proteins in its vicinity. If the frictional feedback is due to the environmental noise at the axon amplified at quantum criticality this is what one expects. Quite generally, quantum criticality would explain the high sensitivity of the thermal parameters on noise. Saltation cannot be responsible for the higher conduction velocity in myelin sheathed portions of axon. The insulation would reduce the environmental noise at the level of axons and thus reduce the frictional feedback from axon to the micro-tubules.

2. The introduction of friction is however problematic in the recent situation. In absence of boundary conditions Sine-Gordon equation predicts for the propagating soliton sequences a continuous velocity spectrum and friction should affect Ω and V rather than phase velocity v but it is not clear whether it can affect v.

   i) In this framework the boundary boundary conditions at the ends of the axon or some sub-unit of axon would dictate the values of v: $\gamma\Omega L/v = n2\pi$ corresponds to periodic boundary conditions (note that $\gamma = \sqrt{1-(v/c)^2} \simeq 1$ holds true). $v = \Omega L/n2\pi$ implies that friction indeed affects also v.

   ii) The relationship states that the time taken by the nerve pulse propagate through the axon is always $T = L/v = n2\pi/\Omega$: this would synchronize neurons and $\Omega \simeq 2\pi$ kHz is suggested by the well-known 1 kHz synchrony difficult to understand in the standard framework where v would be determined by chemistry rather than geometry. Myelin shielding could in this picture guarantee that coherent wave propagation is possible over the entire axon so that boundary conditions can be applied.

   iii) This would give $v \simeq \Omega L/n2\pi < \Omega L/2\pi$. $\Omega = 2\pi$ kHz and $n = 1$ would give for $L \in$ [1 cm -10 cm] $v \in$ 10 m/s-100 m/s corresponding roughly to the observed range of values. For short axons velocity would be lower: for $L = 10$ μm one would have $v = .01$ m/s. For longer axons the value of n could be higher or the axon would decompose into structural units for which periodic boundary conditions are satisfied. The sections between Ranvier nodes have length measured in millimeters as are also the lengths of axonal micro-tubules and 1 mm would correspond to a velocity of 1 m/s. The actual velocity for the myelinated sections varies between 18-100 m/s so that basic structural units should be longer. The proportionality of

v to the radius of axon would follow from the proportionality of the length of the axon or its basic sub-unit (not longer than ~ 10 cm) to its radius: the simplest geometric explanation for this would be in terms of scaling invariance of the axonal geometry consistent with fractality of TGD Universe. In the standard framework this proportionality would be explained by the minimization of dissipative losses in the case of long axons: one cannot exclude some variant of this explanation also now since friction indeed reduces v.

iv) There is an electric field associated with micro-tubules (always in same direction). Could this electric field play the role of external force feeding energy and momentum to the moving soliton sequence to compensate dissipation so that v would have interpretation as a drift velocity?

Q: Can one understand EEG in this framework?

A: Just like kHz waves also EEG generating waves could correspond to propagating soliton sequences. Since V is not affected, the value of $\hbar$ must be much larger and one must have $\hbar \propto f$, where f defines the EEG rhythm. It is known that EEG amplitudes associated with EEG rhythms behave roughly like $1/f$. This can be understood. By Maxwell's equation the divergence of electromagnetic field tensor is proportional to 4-current implying the amplitude of EEG identified as Josephson radiation is proportional J_0/Ω and therefore to $\hbar$. The propagation velocity $v = \Omega L/2\pi n$ of EEG generating waves is rather slow as compared to kHz waves: for $f = 10$ Hz one would have 10 cm long axon $v = 1$m /s. Synchronization results automatically from periodic boundary conditions at the ends of the axons.

Nerve pulses during EEG rhythms would have much slower velocity of propagation and the duration of nerve pulse would be much longer. The maximal charge transfer would be proportional to $1/\hbar$. It would thus seem that EEG and nerve pulse activity should exclude each other for a given axon. Ω is however smaller so that the generation of nerve pulse is easier unless also ion densities are lower so that J_0 (analogous to gravitational acceleration g in pendulum analogy) is reduced. Perhaps this takes place. The consistency with the propagation velocity of micro-tubular conformational (or even gel-sol-gel) waves might pose additional constraints on v and thus on frequencies Ω for which nerve pulses are possible. That ordinary EEG is not associated with ordinary cells might be due to the fact that $\hbar$ is much smaller: the fractal analog of EEG generating waves could be present but these EEG waves would correspond to faster oscillations in accordance with the view about evolution as an increase of $\hbar$.

3.3 Could micro-tubule-axon system perform topological quantum computation?

The proposed picture is consistent with the model of DNA as a topological quantum computer [L7] and with the idea that also micro-tubules could be involved with tqc. The model of DNA as tqc in its basic form assumes that DNA is connected to the nuclear membrane and cell membranes associated with the cell body by magnetic flux tubes such that each nucleotide is connected to single lipid. Tqc programs are coded to the temporal braiding patters of lipids. This requires that lipid layer is liquid crystal and thus below the critical temperature. The flux tube connecting DNA to inner lipid layer and that beginning from outer lipid layer can form single flux tube or be split. If they form single flux tube braiding and tqc are not possible. During tqc the braid strands going through cell membrane are split and the dance of lipids induced by water flow defining time like braiding (hydrophilic lipid ends are anchored to the cellular water) induces braiding of the magnetic flux tubes which write the tqc program to memory. Furthermore, the lifetimes of flux tubes in the connected state must be short enough to prevent the generation of a nerve pulse. This is the case if the temperature is sufficiently below the critical temperature. The ionic supra

currents are identifiable as the observed quantal non-dissipative currents flowing through the cell membrane when tqc is not on.

Centrioles have their own genetic code realized in terms of RNA and they play key role during gene replication when DNA is out of the game. This encourages to think that micro-tubules make possible an independent tqc like process. The question is how micro-tubule-axon system could perform tqc assuming that the recent picture about DNA as tqc [L7] is roughly correct. The assumptions of the model relevant for the recent situation are following.

1. Flux tubes consists of pieces between standard plugs represented by hydrogen bond acceptors ($O=$, aromatic rings,...). For instance, XYP molecules, $X = A,T,C,G$, $Y = M,D,T$ would represent standard plugs and that the transformation $XTP \to XDP + P_i$ represents the splitting of the flux tube and thus of braid strand. The XMPs associated with DNA would represent the ends of the braid strands. The formation of hydrogen bond between water molecule and $O=$ associated with phosphates at the hydrophilic ends of phospholipids would initiate tqc [L7].

2. In the model for protein folding [**?**] free amino-acid corresponds to a codon XYZ in the sense of wobble base pairing meaning that the third nucleotide corresponds to a quantum superposition of colors of nucleotides coding for the same amino-acid. Hydrogen bonds correspond flux tubes also and hydrogen bonds between $N-H$ and $O=$ groups in alpha helices and beta sheets mean a shortcut making it impossible to continue the flux tube from $O=$ further. Only the continuation of the flux tube through non-hydrogen bonded $O=$ acting as a plug is possible. $Y = Z$ rule holds true for the $O = -N - H$ hydrogen bonds and defines folding code. Inside proteins amino-acids correspond to code YZ part of the codon XYZ and inside alpha helices and beta sheets the flux tubes from DNA would end to amino-acids and for them one could have only braiding between DNA and tubulins. Only in the case of non-hydrogen bonded amino-acids the flux tube connection from DNA could continue to the lipid layer and only in this case one could have the generalization of DNA tqc with flux tubes connecting DNA via tubulins to the axonal lipid layer.

Taking this picture as a starting point one can consider several options. For two first options tubulins are basic units. For the third one DNA nucleotides and amino-acids would have this role.

Option I: Tubulins could be connected to the lipid layer of the axonal membrane by flux tubes and the melting of the axonal membrane would induce braiding during the propagation of nerve pulse. α tubulins are accompanied by stable GTPs analogous to single DNA nucleotide so that α tubulin could takes the role of DNA nucleotide with braid strands to lipids having only single color. Compared to DNA tqc this computation would represent much rougher resolution. β tubulins are accompanied by unstable GTPs able to suffer a hydrolysis to GDP. Also this process would correspond to the splitting of flux tube but the connection to tqc remains unclear. One can imagine one/two connected flux tubes to lipid layer represents bit.

Option II: For some years ago I considered the possibility of a gel-sol-gel phase transition proceeding along the surface surface of the micro-tubuli, accompanying nerve pulse, perhaps inducing nerve pulse, and coding for long term sensory memories in terms of 13 13-bit sequences defined by the tubulin helices with bit represented as a conformation of micro-tubule. This hypothesis might be easily shown to be wrong on basis of the available experimental facts already now. Suppose however that this phase transition happens and that the braid strands do not continue from the micro-tubular surface to the cell nucleus. In this case the braiding could be induced by a gel-sol-gel transition accompanying and perhaps generating the nerve pulse at the micro-tubular level and inducing the disassembly of the microtubule to tubulins followed by re-assembly inducing the braiding. Also this braiding would contribute to tqc like process or at least to a memory storage by braiding and options I and II would provide the complete story.

Option III: What about the variant of DNA-membrane tqc for axons? In the model of DNA as tqc these flux tubes continue back to the nucleus or another nucleus: the flux tubes must be split at cell membrane during tqc and this splitting induces the required isolation from the external world during tqc. During nerve pulse the situation would be different and the flow of lipids in liquid phase could induce DNA-lipid layer braiding: the isolation could however fail now. Tqc would explain why the axon melts during nerve pulse.

There are objections against this option.

i) By previous argument only Y-codons of DNA and only non-hydrogen bonded O =s of aminoacids would contribute to the braid strands. This does not look nice.

ii) The idea about magnetic flux tubes emanating from DNA and flowing along micro-tubules interiors and radiating to the axonal membrane looks also ugly: in any case, this would not affect tqc and nerve pulse could be seen as a direct gene expression not conforming with the idea that microtubules define an independent computational system.

iii) One can wonder why also the magnetic flux tubes from DNA could not end to the space-time sheet of the cell exterior if they do so in the case of axon. The justification for 'No' (besides isolation) could be that also cell soma would possess standing soliton sequence like waves and standing nerve pulses in this kind of situation.

The following considerations do not depend on the option used.

1. What comes first in mind is that the braiding codes memories, with memories understood in TGD sense using the notion of 4-D brain: that is in terms of communications between brain geometrically now and brain in the geometric past. In standard neuroscience framework braiding of course cannot code for memories since it changes continually. Nerve pulse sequences would code for long term sensory memories in a time scale longer than millisecond and micro-tubular phase transition could have a fine structure coding for sensory data in time scales shorter than nerve pulse duration. The fact is that we are able to distinguish from each other stimuli whose temporal distance is much shorter than millisecond and this kind of coding could make this possible. Also the direct communication of the auditory (sensory) input using photons propagating along MEs parallel to axon could also explain this.

2. In the model of DNA as tqc nucleotides A, T, C, G are coded into a 4-color of braid strand represented in terms of quarks u, d and their antiquarks. An analogous coding need not be present also now: rather, all braid strands could have same color represented by G of GTP. Tubulins could be seen as higher level modules consisting of order hundred 500 amino-acids. This corresponds to a DNA strand with length of about .5 μm corresponding to the p-adic length scale $L(163)$ which is one of the four magic p-adic length scales ($k = 151, 157, 163, 167$) which correspond to Gaussian Mersennes. This higher level language character of micro-tubular tqc programs would conform with the fact that only eukaryotes possess them.

3. Cellular cytoskeleton consists of micro-tubules. Could micro-tubular tqc -in either of the proposed forms- take place also at the cell soma level? Could DNA-nuclear membrane system define the primordial tqc and micro-tubular cytoskeleton-cell membrane system a higher level tqc that emerged together with the advent of the multicellulars? Is only the latter tqc performed at the multicellular level? The notions of super- and hypergenome encourage to think that both tqcs are performed in all length scales. One can imagine that ordinary cell membrane decomposes into regions above and below the critical point (the value of the critical temperature can be controlled. Those below it would be connected to DNA by flux tube bundles flowing inside the micro-tubular cylinders. Micro-tubular surfaces would in turn be connected to the regions above the critical point. One should also understand the role of $M_{13} = 2^{13} - 1$ 12-bit higher level "genetic code" assignable naturally to micro-tubules. For instance, could the bit of this code tell whether the module defined by the tubulin dimer strand bundle participates tqc or not?

3.3.1 Could Hodgkin-Huxley model provide a phenomenological description?

It is now clear that the physics behind Hodgkin-Huxley model is not consistent with the physics behind the TGD based model of nerve pulse. The cell as gel hypothesis excludes Hodkin-Huxley model even without any TGD based physics. If ionic currents were ordinary Ohmic currents as in the case of soliton model and Pollack's model, Hodgkin-Huxley model might be interpreted as a phenomenological description. In TGD framework the dark currents do not dissipate and the model can serve only a recipe to mimic the time evolution of the ionic currents by a judicious tailoring of the time dependence of ionic conductances.

The current associated with a given ion would be proportional to the sum of the electric forces experienced by the particle:

$$I_X = g_X \left[Q_X e(V_{em} - V_X)\right] \quad .$$

In the catastrophe theoretic variant of the Hodgkin-Huxley model [22], which assumes a wave (Ca^{++} now) triggering the nerve pulse, the values of the ionic conductivities g_{Na}, g_{Cl} and g_K at resting state are $g_{Na} = 0$, $g_{Cl} = .15\ mmho/cm^2$ and $g_K = .24\ mmho/cm^2$ The values of V_X are $V_K = -77$, $v_{Na} = +50$, $v_{Cl} = -46$, when millivolt is used as unit. The value of the resting potential is $v_R = -65$ mV. The vanishing of g_{Na} at the resting value and down to the point, when nerve pulse is triggered, is assumed in Hodgkin-Huxley model and in the catastrophe theoretic model of the nerve pulse [22]. The vanishing of g_{Na} codes for the absence of magnetic flux tubes in TGD framework.

3.4 Model for anesthetic action

The molecular mechanism of the anesthetic action is a fascinating unsolved problem of neurophysiology. Noble gases have very weak chemical interactions. Despite this many noble gas such as Xe, Kr, Ar but to my best knowledge not Ne and He, act as anaesthetics. Also chemically non-inert molecules have quite similar narcotic effect so that chemistry does not seem to matter as Hodgkin-Huxley model would predict.

3.4.1 Simplest model for the anesthetic action

It is known that the narcotic efficiency of anesthetics correlates with their solubility in lipids [45]. Anesthetics also reduce the melting temperature of the lipid layer. Strong pressure increases the melting temperature and it is known that high pressure brings consciousness back. Thus anesthetic molecules dissolved into the lipid membrane should hinder the generation of the nerve pulse somehow and liquid state of the axonal membrane could be the reason for this. The explanation of the soliton model for the anesthetic action [70, 69] is that the metabolic energy needed to generate an acoustic soliton becomes too high when axon is too high above the critical temperature.

To get a useful perspective note that also the problem why ordinary cell and neuronal soma outside axonal hillock do not allow action potentials is poorly understood. The obvious idea is that anesthetized axonal membrane (or at least axonal hillock) is just like the ordinary cell membrane. The model for DNA-cell membrane system as a topological quantum computer requires the liquid-crystal property of the lipid layers of the ordinary cell membrane and neuronal membrane outside axonal hillock. If this is the case, then liquid phase for axonal membrane implied by the anesthetic action would indeed make it more or less equivalent with the ordinary cell membrane. Therefore the question is why the liquid-crystal property of the ordinary cell membrane prevents the generation of the action potential.

1. Pollack's model [33] suggests that anesthetics could hinder the occurrence of the gel-sol phase transition for the peripheral cytoskeleton. Suppose that $\hbar$ increasing phase transition

for the magnetic flux tubes connecting peripheral cytoskeleton to the axon extends them to the axonal exterior and makes possible the influx of monovalent ions inducing gel-sol phase transition.

2. Suppose that the phase transition increasing $\hbar$ is induced by the reduction of the voltage over the axonal membrane (assume to be much smaller than cell potential) inducing almost vacuum property and quantum criticality. Somehow the presence of anesthetics would prevent this. Either the voltage over the membrane is increased in magnitude so that the flow of dark ionic currents to the membrane is not enough to induce quantum criticality or the flow of dark currents is completely prevented. The first option is more economical and could be tested by finding whether the voltage over the axonal membrane (membrane in a solid state) is considerably smaller than that over the ordinary cell membrane (membrane in liquid-crystal state). The first option also predicts that during sleep the increase of cell potential (hyperpolarization) actually corresponds to the increase of the membrane potential.

3.4.2 Could cyclotron transitions of noble exotic ions in theta and delta bands induce lullaby effect?

Just for fun can consider also more exotic explanation for the anesthetic action. If dark weak force is to have any biological role, the cellular environment should induce a generation of anomalous weak isospin due to the charged color bonds inside nuclei of noble gas. This would obviously relate closely to the anomalous properties of water explained in terms of dark matter hierarchy in [F10, J6]. The color bonds carry also em charge so that noble gas atom with single charged color bond would behave like an ion with nuclear charge Z+1 or Z-1 and electronically like ion with full electronic shell due to ionization (say Cl^- or K^+ in the case of Argon). An important point is that the exotic ions are bosons and can form thermally stable Bose-Einstein cyclotron condensates at $k_d = 4$ flux sheets unlike ordinary ion with mass number differing by one unit.

An interesting question is whether some fraction of Cl^- and K^+ ions are actually exotic Argon ions. Also the long ranged color force and dark weak force with range L_w=.2 μm associated with noble gas nuclei in dark phase could be part of the solution of the mystery.

EEG and ZEG bands above theta band correlate with consciousness. The cyclotron frequencies of ions of anaesthetic noble gases are in theta and delta band as are also EEG frequencies during various stages of sleep but for Ne and He this is not the case. This might not be a mere accident. For instance, one could imagine that the strong resonances in theta and delta bands in EEG induced by Xe, Kr, or A could steal the power otherwise going to higher EEG bands and induce a lullaby effect leading to anaesthesia. This effect of course does not exclude the proposed effect reducing the nerve pulse activity.

According to the general model of EEG [M3], the magnetic flux sheets traversing DNA double strands in cell nuclei come in two varieties corresponding to the two possible quantization of magnetic flux as $Z \int BdS = n\hbar(4)$. For $Z = 1$ the field strength is very near to B_E and for $Z = 2$ to $B_E/2$, with $B_E = .2$ Gauss, the strength of endogenous magnetic field explaining the findings of Blackman and others. For instance, left and right brain hemispheres might correspond to $Z = 1$ and $Z = 2$ and the scale for cyclotron frequencies for right hemisphere would be half of that for left hemisphere. During sleep $Z = 2$ cyclotron frequencies are responsible for EEG via the interaction with Josephson junctions generating the satellites $f_c \pm f_J$ of these frequencies, $f_J = 5$ Hz for $Z = 2$ and $f_J = 2.5$ Hz for $Z = 1$.

The cyclotron frequencies of exotic ions $(Xe^+, Kr^+, Ar^+, Ne^+, He^+)$ are (2.15,3.57,7.5,15,75) Hz for $B = B_E$ and (1.08,1.78,3.75,7.5,37.5) Hz for $B = B_E/2$. It would be interesting to check whether EEG contains narrow bands around these frequencies during anesthesia. Also the satellites $f_\pm = f_c \pm f_J$, $f_J = 5$ Hz, could be present. For all noble gas anaesthetics Xe, Kr, and Ar both frequencies are below 7.5 Hz and thus in theta and delta bands. This would encourage to think

that the presence of these bosonic exotic ions amplifies the EEG frequencies usually assigned with the theta and delta bands and in this manner induces anaesthesia.

If this is a correct interpretation then it would be essential that K^+ and Cl^- are fermionic ions: otherwise a lullaby effect would result. Note that the exotic ions of Argon can mimic either Cl^- and K^+. Besides producing the lullaby effect, this mimicry could change the effective concentrations of various ions so that large enough reduction of the resting potential could become impossible.

4 More speculative ideas about nerve pulse and EEG

In order to not frighten the reader I have collected the most speculative speculations about the possible role of charge entanglement and fractally scaled variants of weak interactions in the generation of nerve pulse to a this section. Reader has freedom decide whether to read it or skip to the next section.

4.1 Could scaled variants of weak bosons be key players in the model nerve pulse?

One of the basic predictions of classical TGD is the presence of long range weak and color forces. It took quite a long time to accept this and realize that TGD predicts fractal hierarchy of copies of weak and color physics and that these scaled variants might be crucial for the understanding of living matter and even nuclear and condensed matter physics.

I have done a considerable amount of work in trying to clarify whether this new physics might allow to understand the generation of nerve pulse. Nerve pulse is generated when the voltage over cell membrane is reduced from $\simeq$ .08 V to a critical voltage $\simeq$ .05 V. This means that Josephson frequency is also reduced. Josephson current generates EEG and ZEG patterns as coherent states or Bose-Einstein condensates of photons and Z^0 quanta. This raises the question whether the reduction of Josephson frequency characterizing these quanta could serve as a signal for cell nucleus to induce activities leading to the generation of nerve pulse so that nerve pulse would not be automatic response to the lowering of the resting potential below the critical level.

The basic problem is to understand how resting potential is reduced below the critical value .05 V. One can divide the mechanisms to three types depending on whether ordinary charge flow, reduction of charge entanglement, or exchange of virtual or real W bosons is involved.

4.1.1 Both Em and Z^0 cyclotron BE condensates could be important

Besides em force also long ranged Z^0 and color fields generated by various levels of dark matter hierarchy could play an active role. Exotic weak bosons corresponding to p-adic length scale $k = 113$ and by a factor 2^{-12} lighter than ordinary weak bosons and their dark variants with same masses but Compton wave lengths $L_w(k_d)$ scaled up by a factor λ^{k_d} are assumed to be present and explain besides the anomalous behavior of water also the large parity breaking effects such as chiral selection in living matter. $k_d = 1$ corresponds to $L_w(1) = 1$ Angstrom length scale and $k_d = 2$ corresponds to $L_w(2) = .2$ μm.

The values of k_d in weak sector and em sector are related by $k_d^W = k_d^{em} + 2$. This has important implications.

1. In a given length scale weak cyclotron time scale is by a factor $\lambda^2 \simeq 4 \times 10^6$ longer than corresponding em cyclotron time scale. Hence Z^0 cyclotron transitions are naturally involved with biological functions involving long time scales such as cognition whereas em cyclotron transitions are ideal for functions involving short time scales such as sensory perception which requires sharp time resolution.

$k_d^{em} = 4$ would correspond to the length scale of magnetosphere and cyclotron frequencies in EEG range, most bosonic ions having them in alpha band. $k_d^W = 4$ corresponds to $L_w(4) = .8$ m, body length scale. ZEG is very similar to EEG. Thus em-Z^0 dichotomy would give additional support for the idea [N1] that magnetosphere and biological body have a rough fractal correspondence.

$k_d^{em} = 4$ level corresponding to the length scale of Earth's magnetosphere. In this length scale Z^0 magnetic field $g_Z B_Z = eB$ would correspond to $k_d^W = 6$. The typical time scale .1 second for delta band of EEG would be scaled up by a factor λ^2 to a time scale of order year serving as a kind of drumbeat for the activities of everyday life.

2. $k_d^W = k_d^{em} + 2$ makes possible Z^0 cyclotron Bose-Einstein condensates in length scales shorter by a factor λ^{-2} than in em case. Cooper pairs of exotic neutrinos coupling to $k = 113$ weak bosons are the most obvious candidates for bosons in question. Exotic nuclei obtained when some color bonds of nucleus containing quark and antiquark at its ends becomes charge $u\overline{d}$ or $d\overline{u}$ type bonds have both weak and em charge. Hence Z^0 cyclotron condensates could be of special importance for bio-control by structures having body length scale.

3. The requirement that the quantum model for hearing and memetic code is not lost, implies that exotic neutrinos correspond to M_{127} and thus have mass near to that of electron. $k_d = 0$ cognitive neutrino pairs essential for the realization of memetic code can be realized as wormhole contacts with the light-like causal horizons associated with the throats of contact carrying quantum numbers of neutrino and antineutrino. The net energy of cognitive neutrino pairs can be very small or even vanish due to the strong Z^0 Coulombic interaction energy of the exotic neutrino with Z^0 charged exotic nuclei condensed at $k_d^W = 1$ level. The combined spin flips and cyclotron transitions of the cognitive neutrinos provide a possible mechanism to realize memetic code [J3, M6].

4. Dark $k_d = 1$ exotic neutrinos can topologically condense at the boundaries of $k_d = 2$ flux quanta of Z^0 magnetic field can give rise to neutrino boundary superconductivity by a mechanism similar to that of electronic high T_c super-conductivity [J3]. In the interior of these flux quanta BCS type Cooper pairs are possible and the resulting two super-conductivities are competing at quantum criticality prevailing in some narrow temperature range for which 36-37 K is a good guess as in the case of also electronic high T_c superconductivity.

   Exotic neutrino Cooper pairs (having possibly unit spin) condensed at $k_d = 2$ Z^0 magnetic flux sheets have for $k_d = 2$ cyclotron frequency $f_c \simeq 150$ Hz and cyclotron energy $E_c \sim 20eV$ for Z^0 magnetic field $g_Z B_Z = .1$ Tesla for which flux sheets would have thickness of 2.5 nm, thickness of DNA double strand if obtained by scaling down flux tubes of the endogenous magnetic field $B = .2$ Gauss Hence the cyclotron transitions of exotic neutrino Cooper pairs might be involved with biocontrol in time scale corresponding to 150 Hz.

   Josephson junctions would provide a realization of this control. Thermal stability predicts a minimal Z^0 Josephson voltage of about 86 mV very near to the resting voltage over cell membrane. Corresponding Josephson frequency for $k_d^W = 2$ would be in MHz range. Modulation of this MHz frequency amplitude by 150 Hz amplitude would give rise to Z^0 Josephson radiation and ZEG in MHz range with 150 Hz amplitude modulation.

4.1.2 Generation of charge by a state function reduction of a charge entangled state

MEs are ideal for control purposes since the field propagates with light velocity so that dispersion is absent and the field pattern is arbitrary as a function of time at a given point. Charged W MEs make possible charge entanglement between Bose-Einstein condensate of ions at $(k_W, k_{em}) = (5, 3)$ magnetic body of neuron involving dark Josephson junction with thickness $40 + 40$ m and weak

length scale $L_W(5) = 1.6$ km. Denote the charges of ions in their usual state by Q_n and Q_m: the subscript refers to neuronal interior or magnetic body.

Charge entanglement means that cyclotron B-E condensates of ions with charges Q_n and Q_m develop exotic nuclear charges due to the transformation of $q\overline{q}$ color bonds to $u\overline{d}$ or $d\overline{u}$ type color bonds in the external W field.

If only single charged color bond can be created, the entangled state is of form

$$|Q\rangle \quad = \quad a|Q_n\rangle|Q_m\rangle + b|Q_n+1\rangle|Q_m-1\rangle + c|Q_n-1\rangle|Q_m+1\rangle \tag{8}$$

Since the classical W field inducing the entanglement is real, one must have $|b|^2 = |c|^2$. One has $|b|^2 \propto |W|^2$ in the approximation that the transversal W field associated with ME is constant inside neuron. $Ca^{++,+}$ and $Ca^{++,-}$ exotic ions are the most plausible option but their are also other options as Table 1 below shows. The reason for the preferred role of Ca ions is that Ca waves play a key role in bio-control in a wide range of time scales [43]. That they do not appear in the standard version of Hodgkin-Huxley model conforms with the assumption that they are in dark matter matter phase.

The quantum phase transition reducing the charged entanglement of the Bose-Einstein condensate leads with a probability $|b|^2$ to the state $|Q_n+1\rangle|Q_m-1\rangle$ so that the negative charge of the neuron interior is reduced. The rate for the state function reduction process is proportional to the intensity $|W|^2$ of W boson field and N^2, N the number of bosons in the condensate. The quantum randomness of the process is consistent with the randomness of nerve pulse emission.

If the resulting positive charge is large enough, membrane potential reduces below the value .05 V at which nerve pulse is generated. Only this option is consistent with the model allowing to understand how big leaps in evolution (molecular life, prokaryotes, eukaryotes, animal cells, neurons, EEG) correspond to the emergence of new levels in dark matter hierarchy.

4.1.3 Exchange of exotic W bosons between cell interior and exterior

Exchange of exotic $k_d^W = 2$ $W^{\pm}$ with Compton length of $L_2 = .2$ meters allows charge exchange between charged particles at different sides of cell membrane. This charge transfer mechanism would be nonlocal and essentially quantal. Quite generally, the exchange of $W^{\pm}$ boson could provide a very general non-local mechanism of bio-control by inducing currents of em and weak currents through Josephson junctions. Em and Z^0 fields would in turn be associated with communication and coordination.

If Bose-Einstein condensates are in question the rate of this process is large due to its quantum coherence. There are several candidates for the Bose-Einstein condensates.

1. $k = 127$ exotic quarks inside nuclei couple to $k = 113$ $k_d^W = 1$ weak bosons and their dark variants associated with dark nuclei would couple to $k_d^W = 2$ W bosons. The problem is that the cyclotron energies of atoms are below the thermal threshold for $k_d^W = 2$ so that cyclotron Bose-Einstein condensates are not possible. One can of course consider the possibility that $k = 127$ quarks can appear as free particles in scaled up dark length hadron length scale and that also they or mesons formed by them form Cooper pair Bose-Einstein condensates.

2. $k_d^W = 2$ dark $k = 127$ neutrino Cooper pairs have cyclotron energies above thermal threshold for $g_Z B_Z = .05$ Tesla and are unique candidates in this respect. This transition would change exotic neutrinos to exotic (and dark) electrons coupling only to $k = 113$ weak bosons. Internal consistency suggests that they indeed exist and they might have essentially the same mass as ordinary electron. The decay widths of ordinary gauge bosons do not forbid a scenario in which all fundamental fermions exists as dark fermions with $k = 127$.

3. The exchange of exotic $W^{\pm}$ between $k_d = 2$ dark quarks of dark nuclei and exotic neutrino Cooper pairs ions or exotic electrons at different sides of cell membrane is one possibility. This mechanism induces exotic ionization and charging of nuclear or intramolecular color bonds. If the ions or molecules in question are bosons they can form Bose-Einstein condensates and this would allow the effect to occur coherently and thus increase its rate dramatically. It seems however that even for $g_Z B_Z = .05$ Tesla cyclotron states of exotic ions are thermally unstable for $k_d^W = 2$. This mechanism would however work at higher levels of dark matter hierarchy.

4.2 Some aspects of the model of nerve pulse based on charge entanglement

Charge entanglement induced by W MEs seems to provide a highly plausible mechanism of quantum control with nerve pulse generation representing only a particular application of this mechanism. Therefore the following considerations are restricted to this case.

4.2.1 Quantum parallel dissipation and dissipative quantum computation

Already before the ideas about dark matter hierarchy the notion of self hierarchy led to the notion of hierarchy of quantum jumps with increasing average geometric durations assignable to quantum jumps [K1, K2]. Also the notion of quantum parallel dissipation occurring at levels below a given level of hierarchy emerged naturally. Dark matter hierarchy together with the p-adic hierarchy define naturally this kind of hierarchy. The descriptions of hadrons as quantum coherent systems on one hand, and in terms of quarks and gluons obeying dissipative dynamics governed by kinetic equations on the other hand, would represent one example of this hierarchy.

The charge entanglement generated by W MEs during generation of nerve pulse would represent second example of quantum parallel dissipation. Ionic currents would flow already during the superposition of ordinary and exotically ionized Bose-Einstein condensates. These currents would correspond to the quantal currents discussed in the previous section made possible by the quantal generation of JABs (by Faraday law the voltage along space-time sheets at lower level of hierarchy is affected by the presence of exotic dark ions in the presence of JABs implying closed many-sheeted loops).

If this is the case, TGD would predict no deviations from Hodgkin-Huxley model except those brought by state function reduction and the fact that Ohmic currents are actually quantal currents. Ionic currents would start to flow in the geometric past and would be perceived only after the quantum jump reducing the state to an exotically ionized state would occur. Also ghostly nerve pulses and even patterns of them could be generated since state function reduction can also lead to the ordinary state. An interesting question is whether these ghostly nerve pulse patterns relate to imagination and whether they could make possible dissipative quantum computation (perhaps during sleep)[E9]. The naive expectation is that the probability that quantum jump does not occur during a given time interval decreases exponentially and that the dark time scale in question defines a typical duration for the entangled period.

4.2.2 The role of Ca^{+2} ions

Ca^{+2} ions are perhaps the most important bosonic ions and their dark Bose-Einstein condensates are expected to be key actors in bio-control although also other bosonic ions are very probably involved (see Table 1 below). Ca^{+2} waves are indeed central tool of bio-control and their velocities span a very wide range.

The model for nerve pulse led to a proposal that phase transitions increasing $\hbar$ and thus generating flux tubes between gel phase and its sol-like environment make possible the flow of

mono-valent dark ions from the environment to the gel phase and induce gel-sol phase transition. The propagating gel-sol-gel phase transition would generate nerve pulse, and its fractally scaled variants corresponding to various values of $\hbar$ could generate Ca^{++} waves accompanied by a periodic variation of em potentials. Also the miniature- and micro-potentials associated with the postsynaptic neuronal membrane could correspond to standing Ca^{++} waves with an appropriate value of Planck constant.

A more speculative idea is that charge entanglement involving a periodically varying W boson field could induce Ca^{+2} waves by inducing the $\hbar$ increasing phase transition. The cautious prediction is that the most important time scales in question should come as λ^k, $\lambda = 2^{11}$ multiples of p-adic time scales. The propagation with a finite velocity could correspond to the motion of the second end of W boson ME along tissue or to a phase of W field varying in a direction transversal to the light-like wave vector assignable with W ME.

Ion	f_1/Hz	E_1/eV
$^6Li^+$	50.1	3.3
$^{24}Mg^{2+}$	25.0	1.65
$^{16}O^{2-}$	37.6	2.48
$^{32}S^{2-}$	18.8	1.24
$^{40}Ca^{2+}$	15.0	.99
$^{55}Mn^{2+}$	11.4	.75
$^{56}Fe^{2+}$	10.8	.71
$^{59}Co^{2+}$	10.0	.66
$^{64}Zn^{2+}$	9.4	.62
$^{80}Se^{2-}$	7.6	.5

Table 1. The first columns give the cyclotron frequencies and cyclotron energies for biologically relevant bosonic ions in endogenous magnetic field assumed to have strength $.2 \times 10^{-4}$ Tesla. The third column gives cyclotron energy.

1. Is nerve pulse conduction accompanied by the propagation of Ca^{++} wave?

Hodgkin-Huxley model introduces the velocity of conduction of nerve pulse in a rather ad hoc manner. To my limited knowledge the mechanism behind the finite velocity of conduction of nerve pulse remains poorly understood. In the catastrophe theoretic model of the nerve pulse [22] an unidentified wave triggering nerve pulse is assumed for purely mathematical reasons. Ca^{++} waves as waves guiding the propagation of nerve pulse are a natural guess in this respect. W MEs associated with nerve pulse transversal to axon could extend along its entire length and the variation of the phase of W ME in transversal direction could induce Ca^{++} wave in turn inducing the conduction of nerve pulse with a finite velocity.

One can of course wonder whether the observed Ca^{++} waves can really relate to entanglement oscillations of dark matter Bose-Einstein condensate. This depends on how direct the detection of the waves is: certainly the indirect detection of dark ions based on Faraday effect is possible. Note that Ca^{+2} BE condensate behaves like dark matter is consistent with the fact that Ca^{+2} conductance need not be taken account in the simplest variant of Hodgkin-Huxley model.

2. Ca^{++} waves and synaptic contact

The action potential is known to trigger the transfer of Ca^{+2} ions into the presynaptic terminal and the presence of Ca^{+2} ions is essential for the emission of the neurotransmitters. The synaptic vesicles containing neuro-transmitters fuse with the presynaptic membrane and neurotransmitters are released. Neuro-transmitters bind to the postsynaptic proteins in the postsynaptic

membrane changing their conformation, which in turns leads to ion flows and the generation of micro–potentials generated by transmitter molecules summing up to miniature synaptic potentials. It is known that the emission of the synaptic vesicles is a quantum process and that the emission of a single synaptic vesicle gives rise to a miniature synaptic potential of amplitude of about 1 mV [49].

The most natural interpretation for what happens in synaptic contact is that nerve pulse patterns are transformed to chemical qualia analogous to tastes and odors and that every synapse is specialized to generate particular kind of chemical qualia. These qualia need not be our chemical qualia which in TGD framework are assignable to the primary sensory organs. Neuronal sensory qualia could at our level of hierarchy give rise to emotions. These qualia are shared by the magnetic body ($(k_W, k_{em}) = (5, 3)$ level of dark matter hierarchy). Charge entanglement for subsystems is the TGD based manner to achieve the sharing of mental images and this bring in Ca^{++} and $Ca^{++,\pm}$ B-E condensates.

3. Other functions of Ca^{++} waves

Ca^{+2} currents are also related to the conformational changes of proteins, in particular microtubules, and are believed to be somehow involved with the delocalization of electrons. Ca^{+2} ions are also involved with GTP-GDP hydrolysis. Probably rather low level of dark matter hierarchy is in question in both cases.

Besides this Ca^{+2} ions are involved with local sol-gel transitions associated with the actin micro-filaments driving cell motility, which involves generation of long range order and can be regarded as a self-organization process. Sol-gel transitions occur cyclically and the natural unit for rate is 10 cycles per second. This suggests that multiples of Ca^{+2} cyclotron frequency determine the rates and that the process is quantum controlled by EEG and WEG and corresponds to $k_W = 6$ level of dark matter hierarchy.

4.3 Could cognitive fermion pairs accompany the nerve pulse?

Cognitive neutrino pairs and memetic code words defined by them are the cornerstone of TGD based quantum model of hearing [M6] but the question whether this model really makes sense has remained without answer. Note however that if one accepts the role of exotic W bosons, one cannot exclude cognitive neutrino pairs with interaction range longer than cell membrane thickness.

This highly speculative model whose history is as tortuous as that of nerve pulse model has several variants. Cognitive neutrino pairs could be actually replaced with any wormhole contact involving pair of fermion and antifermion. Only the large Z^0 interaction energy of neutrino wormhole throat making the net rest energy of the pair very small gives cognitive cognitive neutrino pair a preferred position.

An additional support for the notion of wormhole contact has emerged quite recently from the model of DNA as topological quantum computer [L7]. The wormhole contacts carrying quark and anti-quark at their throats and located at the ends of wormhole magnetic flux tubes are the key element in the model of DNA as topological quantum computer and lead to a large number of precise predictions about DNA itself (note that gauge bosons quite generally correspond to wormhole contact like structures).

The question which has remained without a satisfactory answer is whether and how nerve pulse generation could induce the generation of memetic code words as temporal sequences of zero energy cognitive neutrino (fermion) pairs. In this representation the existence of fermion would signify "yes" and its absence "no". For an alternative realization the spin of fermion signifies the two different truth values. The following argument suggests that the model of nerve pulse generation based on W exchange might provide the answer.

The p-adic length scale associated with $k_d^W = 2$ space-time sheet must be shorter than $L_2(2) = .2$ μm. This leaves only $L(k = 157) = 80$ nm into consideration. If cell interior and exterior

space-time sheets are disjoint, wormhole contacts mediating the em and weak gauge fluxes to other space-time sheets must be formed. Em gauge flux must be transferred to a larger space-time sheet.

Weak flux could be transferred also to a smaller space-time sheet, say $k_d^W = 1$ space-time sheet of $k = 113$ weak boson corresponding to $k(eff) = 135$. This flux is not conserved at this space-time sheet in length scales longer than $L(135)$. This wormhole contact would be identifiable as a fermion cognitive pair. The presence of kHz frequency assignable to .05 Tesla Z^0 gauge field at $k_d^W = 4$ and $k_d^{em} = 4$ levels would divide the time axis into bits. This would allow to realize memetic code in its original version in which the presence of fermion, say neutrino, corresponds to "yes" and its absence "no", and nerve pulse sequence would be automatically coded to a sequence of bits represented by the presence/absence of cognitive fermion pair.

5 Many-sheeted neuron

TGD approach allows to make educated guesses concerning the interpretation of various phenomena in neuronal level. This section has been written much before the input from DNA as tqc and the realization that microtubule-cell membrane braids could serve as quantal sensory memory storage based on the braiding of the magnetic flux tubes emanating from the aminoacids of tubulin molecules. This implies obvious updatings of the text of this section left to the reader.

5.1 Neuronal consciousness

The fractality of consciousness encourages the view that neurons and corresponding magnetic bodies are conscious organisms having receiving sensory input and forming sensory representations at their magnetic bodies, and generating motor actions. One can see associations at neuronal level as a process in which neuronal sub-self induces mental images inside the postsynaptic neuronal self. Neuron could be seen as a fractally scaled down version of a sensory pathway.

The sensory input of a neuron is determined by the inputs from active pre-synaptic neurons. Postsynaptic receptors are analogs of ordinary sensory receptors and they determine the sensory qualia and primary sensory mental images of the neuron about external world (also ordinary cells have sensory receptors and sensory representations but only about nearby environment). Microtubuli inside dendrites are the analogs of sensory pathways, and cell membrane and cell nucleus could play the role of the neuronal skin and brain. Both could give rise to sensory representations. Sensory representations at the magnetic and Z^0 magnetic body of nucleus would be generated by DNA. Neurons would have sensory qualia and neuronal receptors and receptors at the surface of any cell could give rise to the analogs of tastes and smells. Cells could also see and hear at some wave length ranges and the micro-tubuli associated with the cilia span a length scale range containing visible frequencies.

The neuronal sensory input leads to a generation of a sensory representations at the magnetic body of neuron. A rough estimate for its size results by assuming that the ratio of the length of MEs involved to the size of the system is constant. By scaling from the size of brain hemisphere of about 8 cm corresponding to EEG frequencies to cell nucleus size of about one micro-meter, one finds that frequencies involved are above 10^5 Hz. $k_{em} = 3$ level of hierarchy of Josephson junctions would correspond to 10^4 Hz frequency as Josephson frequency having 5 Hz frequency as EEG counterpart. The counterpart for .5 Hz frequency scale of DNA sequences assigned to right hemisphere neuronal nuclei at $k_{em} = 4$ level of dark matter hierarchy would correspond to 1 kHz frequency at the level of neurons. Also neuronal membrane can give rise to sensory representations as probably does also skin, and for a neuron size about .1 mm the counterparts of EEG frequencies would be above kHz. Frequencies of MEs must indeed be above kHz in order that the magnetic

body of the cell has enough time to generate the motor action as a response. Part of the motor action of neuron is generation of nerve pulse pattern by Z^0 ME from Z^0 magnetic body.

5.2 Functions of nerve pulse

Nerve pulses inducing generalized motor action represent pushes and pulls in spin glass energy landscape of brain. These pushes and pulls induce motion in the spin glass landscape and generate somehow both neuronal and our emotions. Transmitters mediate nerve pulses from presynaptic neuron to postsynaptic neuron and modify the properties of the synapse and of the postsynaptic neuron. Fast neurotransmitters controlling directly ion channels are involved with the process and the relevant time scale is one millisecond. No long term change of the postsynaptic neuron is involved. Slow neurotransmitters involving second messenger action are involved with the modulation of the response of the postsynaptic neuron, and the time scales can be of order of minutes. In this case the properties of the postsynaptic neuron are changed. Emotional reactions involve typically slow transmitters and their effect can be regarded as a generalized motor action inducing motion of the neuron in the spin glass energy landscape of the neuron.

5.2.1 What the specialization of sensory pathways to sensory modalities means?

Sensory pathways are specialized to produce some specific sensory qualia. How this specialization correlates with what happens at the neuronal level?

1. If one accepts the notion of magnetic body, it is not too difficult to accept the idea that the magnetic bodies associated with the sensory organs are the seats of the sensory representations whereas higher levels of CNS are responsible for symbolic and cognitive representations accompanying sensory representations. TGD based view about long term memories makes it possible to defend this view against standard objections such as phantom limb phenomenon, projected pain, and the stimulation of sensory hallucinations electrically. One cannot exclude the possibility that even the sharing of mental images with the objects of external world contributes to the conscious experience.

2. An almost diametrically opposite view is that qualia are like colors of a map and coloring is decided at quite high level of sensory processing.

These views need not be mutually exclusive. Sensory qualia seated at sensory organs can serve as the colors of the map if sensory receptors and brain form single quantum system in which entanglement with and back projection to the structures defined by sensory receptors is essential. This back projection could transform the primary mental images. This view would also explain the rapid eye movements during REM sleep and oto-acoustic sounds.

The axons for which temporal sequences of cognitive neutrino pairs identifiable as bit sequences determine the contents of the experience, would give rise to a 'Boolean modality' representing higher level cognition. The assumption that the electric oscillations induced by auditory input mediated by Z^0 MEs is responsible for the generation of memetic codons, gives further support for the idea that entire sensory pathway and sensory receptors are responsible for the qualia.

In this picture association areas could be seen not as cognitive areas, where sensory input is transformed to cognitive output, but areas in which the mental images associated with various symbolic and cognitive pathways fuse to a single mental image. Therefore the term association would be somewhat misleading. A genuine association can be seen to result when a sub-self wakes up sub-self by nerve pulse patterns and is experienced by a higher level self as two subsequent mental images.

5.2.2 Could nerve pulse patterns realize the memetic code?

TGD based model of cognition allows to construct a model for memetic code in which sequences of 126 cognitive neutrino pairs of total duration of about .1 second correspond to Boolean statements or also integers in the range $\{1, 12^{126}\}$ in binary representation. The model for the physical realization of the memetic code is discussed in more detail in [L1] and here only the basic idea will be described.

The model for the memetic code assumes that antineutrinos resides in the strong Z^0 magnetic field associated with the cell membrane and having the direction of the axon. The antineutrinos have suffered spontaneous Z^0 magnetization. Memetic codons consisting of (almost) 127 bits are realized as temporal sequences of spontaneous Z^0 magnetization of antineutrinos at $k = 151$ cell membrane space-time sheet. The ground state with all bits in the direction of the Z^0 magnetic field does not represent consciously anything so that the number of representable bit sequences is $M_{127} = 2^{127} - 1$ which corresponds to almost 127 bits.

Memetic codons are generated by Z^0 magnetic pulses reversing the direction of local Z^0 magnetization. The magnetic transition frequency is energy difference for states $(n+1, up)$ and $(n, down)$ for cognitive antineutrinos of opposite spin in the strong Z^0 magnetic field of the axonal membrane. There is however a "miracle" involved. The magnetic transition frequencies of muonic and tau neutrinos for the transitions between states $(n+1, up)$ and $(n, down)$, are in the range of ELF frequencies and that for the largest possible value of the axonal Z^0 magnetic field this frequency is slightly higher than the maximal frequency of nerve pulses. Hence the duration of nerve pulse implies automatically that it generates harmonic perturbation giving rise to spin flips of neutrinos [L1, M6].

The basic objections against the idea that nerve pulses generate memetic codons are following.

1. The minimum time interval between nerve pulses is slightly longer than required by memetic codon.

2. The prediction would be that high level linguistic cognition is everywhere in brain. Rather, higher level cognition should be associated with the neurons at multi-modal associative regions of cortex [L1] or with cognitive neural pathways leading to these areas. Only humans possess the parietal-occipital-temporal association region combining somatosensory-, visual- and auditory inputs into associations and giving meaning to the objects of the perceptive field. Perhaps the emergence of this associative region associating Boolean statements with sensory features has led to Homo Sapiens.

3. Ordinary nerve pulse patters suggest strongly frequency coding rather than refined memetic code. In the case of memetic code it would mean roughly 64 nonequivalent codons. This in fact might be enough to understand the basic phonemes of language as expressions of memetic codons.

These arguments suggest that nerve pulse patterns give rise only to a frequency coding such that only the frequency of the bits differing from the standard value is of significance. The intensity of sensory input, motor output, and emotional expression could be coded in this manner. Z^0 MEs can generate also oscillations of the membrane potential and it is known that this kind of oscillations accompany hearing. These oscillations could also induce reversal of Z^0 magnetization and could allow to realize memetic code in full complexity.

5.2.3 Generation of declarative long term memories at micro-tubular level

The TGD based model of declarative long term memories is based on the mirror mechanism with brain and body effectively serving as time like mirrors from which negative energy MEs are reflected

as positive energy MEs. Long term memories are coded to subjecto-temporal changes of the micro-tubular conformations [K2] which allow a huge number of almost degenerate configurations, and the transitions between these configurations generate Z^0 MEs (or equivalently, gravitonic MEs) with ultra-low frequencies determined by the time span of the long term memory. The natural first guess is that the nerve pulse patterns accompanied by Z^0 MEs are an essential part of the process of building long term memories by inducing the motion of the axonal micro-tubuli in the spin glass energy landscape. Nerve pulse could be also accompanied by a separate wave propagating along the axonal micro-tubuli and containing much more detailed information about the sensory input specifying the content of declarative long term memories. This would mean huge information storage capacity and also explain why the axonal lengths associated with the sensory pathways are maximized.

A model for the cognitive code associated with with micro-tubuli is discussed in [H8]. The model is based on $13 \times 13 = 169$ bits defined by single full turn for 13 helical tubulin strands consisting of 13 tubulins each. Since only the changes of tubulin conformations contribute to the micro-tubular conscious experience, only $2^{169} - 1$ patterns code for conscious experiences. Therefore the code represent only 168 full bits and the remaining almost bit could define some kind of parity bit. The presence of a sufficiently strong external electric field along the micro-tubule would imply that the change of bit is replaced with a pattern of $b \to b+1 \to b$ transitions leading from the ground state to excited state and back to the ground state.

An interesting possibility is that micro-tubuli define a cognitive code above the memetic code in the hierarchy of cognitive codes so that biology would not reduce to neither genetic nor memetic code. The changes of the micro-tubular conformation patterns could be coded to 2^{126} memetic codons represented by field patterns associated with MEs. The $64 \to 21$ correspondence for DNAs and aminoacids would be generalized to $2^{169} - 1 \to 2^{127} - 1$ correspondence such that 168 full bits would be mapped to 126 full bits. The degeneracy would be $6log(2)/log(21) \simeq 1.39$ for the genetic code and $168/126 = 1.33$ for the micro-tubular code.

5.3 Functions of transmitters

It is an interesting challenge to try to understand the role of various information molecules, in particular neurotransmitters, in TGD inspired conceptual framework.

5.3.1 Information molecules as quantum links in quantum web?

One particular challenge is to find convincing "reason why's" for what happens in the synaptic contacts. Why myriads of neurotransmitters are needed: inhibition, excitation and neuro-modulation could indeed be carried out in much simpler manner?

1. Information transfer is certainly in question and a natural assumption is that the information is conscious quantum information. If so, it is not the transfer of the neurotransmitter molecules which is essential but the transfer of bound state entanglement of these molecules with the environment and thus of conscious information. This is in accordance with the computer metaphor: neurotransmitters would be like links to different pages in the web activated in the transfer process analogous to sending an email containing a list of links plus text. Also a transfer of usable energy could be involved: the positive energy MEs transferred could provide their energy to the postsynaptic cell unless they are used to energize the transfer process. Besides neural transmitters blood cells and various molecules transmitted by blood and lympha could be carriers of quantum links and hormonal action at the deeper level would be quantum communication in this sense.

2. When information molecules and receptors form a quantum bound state, macro-temporal quantum coherence is generated and this correspond at the level of conscious experience

a multi-verse state of 'one-ness' and from the point of information processing a quantum computation like process [K2]. One could also see information molecules and receptors as representative of opposite molecular sexes. The resulting non-entropic mental image corresponds to sensory qualia of the neuron analogous to smells and tastes. In principle, each neurotransmitter gives to a distinct neuronal taste or smell. Also neuronal analogs of vision and hearing are possible. Micro-tubuli indeed give rise to infrared vision in the case of bacterial cells.

3. This picture is consistent with the interpretation of neurotransmitter induced experiences as kind of chemical qualia analogous to tastes and odors and giving rise to emotions at our level of self hierarchy.

5.3.2 Excitation and inhibition

Excitation and inhibition are seen as basic functions of neurotransmitters. More precisely, the attribute excitatory/inhibitory can be assigned with a given transmitter-receptor combination. Gardener metaphor states that brain is a gardener allowing particular plants, now mental images having neural firing patterns as neurophysiological correlates, to flourish. One could argue that this kind of selection is reasonable in order to use metabolic resources optimally. One must be however very cautious here. Paradoxically, the metabolism during synchronous firing does not seem to increase [55]. This finding has two mutually non-exclusive explanations.

a) Remote metabolism involving the generation of negative energy MEs received by glial cells serving as a storage of metabolic energy is involved.

b) Inhibition could require actually more energy than excitation: neural firing would occur spontaneously when the energy feed to the system is subcritical. At least for the inhibition caused by hyperpolarization this view might make sense. One can say that the gardener would actively prevent the growth of some plants. Inhibition would be censorship preventing a spontaneous generation of mental images in accordance with the vision of Huxley about brain as a filter which prevents conscious experience rather than creates it. The hypothesis that bio-control is quite generally based on this principle is attractive since it is easier to prevent a complex process to occur spontaneously than to force a complex process to occur in a desired manner.

Option b) would explain several paradoxical looking findings about the correlation of inhibition with the level of self control. The amount of inhibition increases and the behavior becomes more controlled and "civilized" as one climbs up in the evolutionary tree being highest for humans. Inhibition is higher for adults than for children as is also the level of self control. Inhibition is dramatically reduced during the process of physical death. In all these cases the reduced inhibition would naturally correlate with the reduction of the metabolic feed. Inhibition is also reduced during several altered states of consciousness and these states of consciousness involve also a high level of relaxation.

If the reduced inhibition means a reduction of energy feed, a depletion of energy resources is an unavoidable outcome. This leads to a spontaneous generation of negative energy MEs by starving neurons making possible remote entanglement and remote metabolism. In particular, synchronous neural firing would involve also remote metabolism so that option a) is not excluded by b). The generation of episodal long term memories and various kinds of remote mental interactions would be an automatic side product. The memory feats of synesthetics indeed correlate with a dramatic reduction of metabolism in left cortex; various remote mental interactions are reported to occur during altered states of consciousness; and there are reports about the association of telepathy, precognition and poltergeist type phenomena with the physical death of a close relative or intimate friend.

On the other hand, if inhibition means heightened metabolic energy feed, it also reduces the need to generate negative energy MEs. The reduction of entanglement with the environment

means among other things fewer shared mental images. Therefore the increase of inhibition would be a correlate for the increasing privacy of conscious experience. Ironically, the physical well-being would more or less unavoidably lead to the alienation and unhappiness suffered by so many members of post-modern society.

6 A model for the effective electronic super-conductivity in axons

Also the following model for axonal electronic super-conductivity was constructed before the progress induced by the model of DNA as tqc and the inspiration coming from the model of nerve pulse by Danish researches [69] and is not completely consistent with the new model. I however decided to keep the text because it reflects the development of ideas and with a reasonable amount of work could be modified to the new situation.

Hafedh Abdelmelek and collaborators [54] have found evidence for effective super-conductivity in the sciatic nerves of both endotherms (rabbit) and poikilotherms (frog). The basic finding is that the resistance of the sciatic nerve is reduced by a factor of about ten below a critical temperature at the lower edge of the range of the physiological temperatures. The reduction of the temperature occurs inside a narrow temperature range ΔT, $\Delta T/T_c \sim .04$. This suggests effective super-conductivity. Furthermore, the critical temperature T_c for the breaking of the effective super-conductivity raises from 240 K to 300 K in the transition from poikilotherms (say frog) to endotherms (say rabbit).

These findings seem to be consistent with the following view.

1. Nerve pulse generation involves a mechanism inducing a flow of ions between axonal interior and exterior and induces at the same time the breaking of super-conductivity [M4]. At too low temperatures nerve pulses cannot be generated because the breaking of the super-conductivity is not possible. Therefore the critical temperature must be below the range of physiological temperatures and explains the difference between poikiloterms and endotherms.

2. In myelin sheathed regions the breaking of the effective super conductivity does not occur or the critical temperature is higher and the signal carried by the nerve pulse is transformed to an effective or genuine supra current. A small pulse like perturbation of the membrane potential could propagate still.

3. Poikilotherms can survive only if nerve pulse conduction is possible down to about 240 K which represents lower bound for the temperature of environment. Endotherms can keep the body temperature above 300 K and so that T_c can be as high as 300 K. This is good for survival purposes since high T_c minimizes ohmic losses related to nerve pulse conduction.

The recent model for nerve pulse generation favors somewhat different view. The melting temperatures T_m of the axon and microtubular surface and quantum critical temperature T_c of high T_c super-conductivity are the critical parameters. The generation of the nerve pulse is possible only if T is slightly above T_m. T_m can vary in a wide range and can be controlled genetically. Same could be true for T_c since external perturbations amplified by quantum criticality are expected to affect it. This would explain different values of T_c for poikilotherms and endotherms. The critical temperature for super-conductivity would pose only an upper bound for the temperatures at which organisms can survive whereas quantum criticality of various membranes would constrain this temperature to a narrow range.

6.1 Many-sheeted space-time and connection between thermal de Broglie wavelength and size of the space-time sheet

The concept many-sheeted space-time is needed to understand super-conductivity and breaking of super-conductivity. Parallel space-time sheets with distance about 10^4 Planck lengths form a hierarchy. Each material object (...,atom, molecule, ..., cell,...) corresponds to this kind of space-time sheet. The p-adic primes $p \simeq 2^k$, k prime or power of prime, characterize the size scales of the space-time sheets in the hierarchy. The p-adic length scale $L(k)$ can be expressed in terms of cell membrane thickness as

$$L(k) = 2^{(k-151)/2} \times L(151) \ , \tag{9}$$

$L(151) \simeq 10$ nm. These are so called primary p-adic length scales but there are also n-ary p-adic length scales related by a scaling of power of $\sqrt{p}$ to the primary p-adic length scale.

The characteristic temperature scale for particles of mass M in a thermal equilibrium at the space-time sheet characterized by $L(k)$ is given in terms of the zero point kinetic energy associated with the space-time sheet

$$T(k) \quad = \quad n \times E_0(k) = n \times n_1 \times \frac{\pi^2}{2ML^2(k)} \ , \tag{10}$$

where n and n_1 are numerical constants not far from unity (for convenience the units $k_B = 1$, $\hbar = 1$, $c = 1$ are used). $T(k)$ decreases very rapidly as a function of the p-adic length scale $L(k)$. This equation relates the p-adic prime of space-time sheet to T and M of particles present in the sheets forming join along boundaries condensate. Of course, the size L of space-time sheet characterized by k can vary in the range $[L(k), L(k_>]$ and $T \propto 1/L^2$ is an attractive guess for the dependence of the temperature on the size of the space-time sheet. One can interpret $T(k)$ as a critical temperature at which the p-adic prime characterizing the space-time sheet changes.

6.2 Magnetic flux tubes as effective super-conductors and breaking of super-conductivity

The model for bio-superconductivity and its breaking relies on the following picture.

1. Magnetic flux tubes of Earth's magnetic field (in particular) characterized by $k = 169$ and having a minimal thickness about 5 μm correspond to tubular space-time sheets. The magnetic flux tubes of endogenous magnetic field $B = .2$ with $n = 5$ characterizing the value of the scaled up Planck constant $\hbar = n\hbar_0$ [C7] and the unit nh_0 of magnetic field magnetic flux and $k = 169$ characterizing the p-adic length scale define second option consistent with the identification of 15 Hz as cyclotron frequency of Ca^{++}. In this case the value of magnetic flux is $2h_5$ and the scaled down magnetic field $B_{end}/2$ required by the sleep time EEG would correspond to single flux quantum. Flux tubes would have thickness of about 25 μm corresponding to a size of a large neuron.

   In the absence of both larger and smaller space-time sheets, the flux quanta can act as 1-D super-conductors since cyclotron energy scale, which by the quantization of the magnetic flux behaves also as $1/L^2(k)$, is larger than de Broglie temperature for sufficiently high values n of the magnetic flux (implying thicker flux tube). More generally, one can consider the possibility of a hierarchy of magnetic flux tubes inside magnetic flux tubes corresponding to the sequence $k = 167, 163, ...$ as especially interesting candidate since $k = 151, 157, 163, 167$ define Gaussian Mersennes $(1 + i)^k - 1$. Each of these flux tubes can be a super-conductor.

Bio-super-conductivity is assumed to be due to this mechanism. Of course, only space-time sheets corresponding to only some of these p-adic length scales could be present and this would be crucial as far as super-conductivity and its breaking is considered. The study of the effects of external magnetic fields on the axonal conductivity might provide valuable information about the role of magnetic fields.

2. Super-conductivity can be broken by a temporal leakage of the Cooper pairs to larger space-time sheets if present. These Cooper pairs are kicked back by thermal photons. System is an effective super-conductor in the sense that Cooper pairs are not destroyed in the breaking of super-conductivity and an effective ohmic conductor in the sense that dissipation is present. Super-conductivity can be also broken by thermal kicking of the Cooper pairs to smaller space-time sheets. In this case there is however a restriction posed by the fact that the zero point kinetic energy of the particle increases from $E_0(k)$ to $E_0(k_<)$, where $k_<$ ($k_>$) is the largest (smallest) the prime smaller (larger) than k. Thermal energy is needed to achieve this. For the leakage to occur, one must have

$$T > nE_0(k) \quad = \quad T(k) \ . \tag{11}$$

Some numerical constant n is involved here. Note that the temperature at super-conducting space-time sheets is much lower than the critical temperature and the temperature at atomic space-time sheets.

3. The prediction is that the conductivity decreases in a stepwise manner at temperatures $T = T(k)$ as the temperature increases, and that the smallest value of k for current carrying space-time sheets gradually decreases as $k = 169 \to 167 \to 163 \to 157 \to 151 \to ....$ The behavior of the conductivity in the sciatic nerve seems to represent one particular step of this kind. The primes $k = 167, 163, 157, 151$ are expected to be especially important in living matter since they corresponds to the so called Gaussian Mersennes and p-adic length scales in the range 10 nm-2.56 μm [J1, J2].

4. For a space-time sheet having $k = k_0$, the leakage of supra-current is induced by the formation of join along boundaries bonds between $k = k_0$ space-time sheets and $k \geq k_0$ space-time sheets. The leakage to the smaller space-time sheets can be also induced by radiation with frequency corresponding to the increment of the zero point kinetic energy and the transversal electric field involved with radiation can be regarded as inducing the force driving the particles to smaller space-time sheets or back.

5. The strange findings indicating that DNA can behave like a super-conductor [31], an ohmic conductor [27], or an insulator could be perhaps understood in terms of the local architecture of the many-sheeted space-time. If only atomic space-time sheet is present, DNA would behave as insulator. If larger space-time sheets are present DNA behaves as an effective ohmic conductor in the sense that dissipative effects are present. If only single larger space-time sheet is present, super-conductivity is possible so that the manufacturing of super-conductors should reduce to space-time engineering.

6.3 Quantitative model for the breaking of super-conductivity

The dropping (or leakage) of electronic Cooper pairs from $k = k_0$ (say $k_0 = 151$ corresponding to cell membrane thickness) space-time sheet to larger space-time sheets possibly present and followed by a thermal kicking back to $k = k_0$ space-time sheet is a good candidate for the mechanism causing the breaking of magnetic super-conductivity.

The conductivity as a function $\sigma(k)$ of the p-adic length scale $L(k)$ should characterize the mechanism quantitatively. If the thermal energy $E_{th} = T$ satisfies the condition

$$E_0(k) - E(k_>) < T < E_0(k_<) - E(k) \ ,$$
$$E_0(k) = n_1 \times \frac{\pi^2}{4m_e L^2(k)} \ , \tag{12}$$

one can say that the space-time sheet k is the effective carrier of the current.

The mechanism predicts that the increase of the temperature is accompanied by a sequence of phase transitions in which the value of k characterizing the effective carrier of the current decreases in a stepwise manner: $k = 169 \to 167 \to 163 \to 157 \to 151 \to ....$ These transitions occur at temperatures $T(k) = n \times E_0(k)$, n a numerical constant. This picture is consistent with the observation that the reduction of resistance occurs in a very short temperature interval ΔT: $\Delta T/T \sim .04$.

A more concrete picture is obtained by decomposing the friction force to a sum of forces resulting from dropping from say $k = 151$ to $k = 157163, 167, ...$ and being kicked back. This gives

$$\begin{aligned} F &= K(k)v \ , \\ K(k) &= \sum_{k_i > k} \kappa(k_i) = \kappa(k_>) + K(k_>) \ . \end{aligned} \tag{13}$$

The condition $F = qE$, $q = 2e$, gives for the conductivity defined by $j = nv = \sigma(k)E$, E electric field, the expression

$$\frac{1}{\sigma(k)} = \frac{K(k)}{nq} = \frac{\kappa(k_>)}{nq} + \frac{1}{\sigma(k_>)} \ . \tag{14}$$

What this means that the space-time sheets correspond effectively to resistors in series.

From the experimental findings for frog, for the transition from $k = 157$ to $k = 151$ the term $\kappa(157)$ must be by about a factor 10 larger than the sum of terms term $\kappa(k)$, $k > 157$. The fractal scaling

$$K(k) \propto \frac{1}{L^\alpha(k)} \propto 2^{-\alpha k/2} \tag{15}$$

with $\alpha \simeq 1.1$, suggests itself.

The standard classical model for the dissipative force implies that the force is inversely proportional to the free path $l(k)$ of the particle and by naive scaling symmetry l would be naturally proportional to the p-adic length scale $l \propto L(k)$ giving $\alpha = 1$. $\alpha > 1$ for $K(k)$ means that the free path has a fractal dimension slightly larger than one. The anomalous dimension is due to the many-sheeted nature of the free paths implying the presence of the higher order terms in the expansion of $K(k)$. Indeed, in the lowest order the model based on the naive scaling dimension -1 for $\kappa(k)$ predicts

$$\frac{\sigma(151)}{\sigma(157)} \simeq 1/8 - 1/64 \simeq .11 \tag{16}$$

in consistency with the measured reduction of the resistivity. Needless to say, this prediction provides a strong support for the p-adic length scale hypothesis and the notion of many-sheeted space-time.

6.4 Application at axonal level

It is interesting to apply the model for the breaking of super-conductivity in the case of axon.

6.4.1 Understanding the critical temperature

The model for the nerve pulse generation predicts that "bridges" are formed between $k = k_0 > 151$ (say $k_0 = 169$) and $k = 151$ space-time sheets making possible the flow of ions between cell interior and exterior. Super conductivity is broken provided that the temperature is sufficiently high. For electron Cooper pairs ($M = 2m_e$) the zero point kinetic energy at the cell membrane space-time sheet is from Eq. 12

$$E_0(k = 151) = n_1 \times 312.25 \text{ K} \ . \tag{17}$$

n_1 is some numerical constant not too far from unity. $n_1 = 1$ corresponds to a temperature 42.25 C. The identification as the critical temperature gives quite satisfactory agreement with the experimental values varying from 240 K to 300 K. Note that the requirement $T > T_{cr}$ for the physiological temperatures means that $k = 151$ cell membrane space-time sheet is the effective current carrier in the presence of larger space-time sheets.

If the join along boundaries bond connecting $k = 169$ and $k = 151$ space-time sheets contains a strong enough transversal electric field, the supra current can flow only in one direction. It seems that in the case of cell membrane the leakage of electronic Cooper pairs to the negatively charged cell interior is forbidden by this mechanism. The absence of the join along boundaries bonds between cell membrane and cell exterior assumed to be generated during the nerve pulse in the TGD based model of the nerve pulse [M4] in turn implies that the leakage cannot occur to or from $k = 169$ space-time sheets at all. Therefore both $k = 151$ and $k = 169$ space-time sheet might be genuinely super-conducting and only nerve pulse conduction would be accompanied by the breaking of super-conductivity.

6.4.2 Predictions for the critical temperature and resistance

Fractality allows to make definite quantitative predictions for the critical temperature.

1. For $k = 163$ conductivity the critical temperature is predicted to be by a factor $2^{157-151} = 64$ lower than for $k = 157$ conductivity. This gives $T_c(163) = 4.9$ K for $T_c(157) = 300$ K. The upper bound $T_c = 4$ K for the critical temperature for super-conductivity in molecular crystals is reported in [28]. This would correspond to $T(157) = 240$ K measured in the case of frog. The predicted lowering of the resistance at this critical temperature for nerve conduction might be testable.

2. The observation that DNA attached between carbon and rhenium electrodes becomes super-conducting below the critical temperature of about 1 K for rhenium [31] allows the possibility that DNA becomes super-conducting already at about $T_c(163) \simeq 4-5$ K but that the rhenium acts as the weak link in the super-conducting circuit.

3. Cell membrane thickness L might vary and the natural guess is that the critical temperature is inversely proportional to $1/L^2$. If this is the case, the ratio of cell membrane thicknesses for frog and rabbit should be

$$\frac{L(frog)}{L(rabbit)} = \sqrt{\frac{T(rabbit)}{T(frog)}} = \sqrt{5/4} = 1.12 \tag{18}$$

for $T(rabbit) = 300$ K and $T(frog) = 240$ K.

4. A further prediction following from the fractal model for the conductance (Eq. 15) is that also the $k = 157 \rightarrow 163$ at about 4-5 K involves a 10-fold reduction of resistance. Also this prediction might be testable for nerves.

6.4.3 What happens in saltation?

An interesting question is what happens in the saltation over the myelin sheathed portions of the nerve. According to the TGD based model of nerve pulse [M4], the Z^0 ME ("massless extremal", "topological light ray" moving with effective velocity equal to the conduction velocity of nerve pulse acts as a bridge between cell membrane ($k = 151$) and cell exterior ($k = 169$) space-time sheets and in this manner allows the leakage of ions from cell interior to exterior and vice versa inducing the physiological effects of nerve pulse. Z^0 ME could propagate along the myelin sheath rather than along the axon inside. Therefore nerve pulse would not be generated. The following picture about saltation suggests itself.

1. The transformation of the nerve pulse to an electronic $k = 151$ or $k = 169$ supra current propagating rapidly through the myelin sheathed portion would make possible a rapid signal transmission without physiological effects. Inside myelin sheathed portions of the axon the leakage to $k = 169$ space-time sheets would be impossible by the mechanism described above irrespective of the value of the critical temperature.

2. Nerve pulse conduction involves also communication and interaction between different space-time sheets and therefore necessitates the leakage of electronic Cooper pairs from $k = 151$ cell membrane space-time sheet. Therefore the critical temperature must be below the range of the physiological temperatures. Endotherms have an evolutionary advantage since the higher critical temperature implies that the dissipative effects associated with the nerve pulse conduction are weaker.

   Whether electronic supra current in the myelin sheathed portions of the axon propagates along $k = 151$ or $k = 169$ space-time sheet or along both plus possibly along some other space-time sheets, remains unclear. Note that the critical temperature in myelin sheathed regions could be higher than the physiological temperature. The endogenous magnetic field $B = .2$ Gauss suggested by the work of Blackman and others corresponds to a flux tube radius $L = sqrt5/2 \times L(169) \simeq 1.58L(169)$. $nL(167)$ with $n = F_0 = 3$ would give $L = 1.5L(169)$. $k = 167$ in turn corresponds to Gaussian Mersenne $(1+i)^k - 1$, $k = 167$. If one scales only in one direction then the scaling factor is $5/2$ and $5L(167)$ would give the correct result. $n = 5$ corresponds the minimum value of n making possible topological quantum computation [E9].

It is interesting to notice that Evan Harris Walker [56] has developed a quantitative theory in which the tunnelling of electrons through the synaptic contact is the basic step of synaptic transfer. The theory applies also to ephapses in which electric transfer of the nerve pulse takes place. Theory explains the differences between ephapses and synapses and also the morphology of synapses and ephapses finds natural explanation. This kind of tunnelling might be induced by the formation of 151-169 Z^0 ME contacts at presynaptic cell and 169-151 Z^0 ME contacts at the postsynaptic cell.

7 Relating the model of nerve pulse with the micro-tubular level

The relationship of the presumed quantum dynamics of the cell interior to the nerve pulse is the basic topic of quantum consciousness theories. Micro-tubular conformational dynamics; gel-sol

phase transition of the cytoplasmic water inducing the depolymerization of the actin polymers; the parallelization of micro-tubuli possibly making possible a coherent generation of infrared em radiation; and Mg^{+2} and Ca^{+2} ions as controllers of polymer stability, are some of the most important pieces of the jigsaw. The hierarchical model of Alex Kaivarainen emphasizing these aspects provided crucial pieces of information [57] allowing to construct many-sheeted view about this process. The hierarchy of condensed matter excitations introduced by Kaivarainen corresponds in TGD framework to the hierarchy of space-time sheets whereas the molecular Bose-Einstein condensates of Kaivarainen correspond to BE condensates of various bosonic ions and Cooper pairs at various cold space-time sheets. The classical article of Nanopoulos summarizing basic facts and various ideas about micro-tubuli [50] has been a continual source of information and inspiration and is warmly recommended.

One important element are negative energy IR MEs having phase conjugate laser beams [23] as physical counterparts. First of all, they make possible intentional action at the micro-tubular level: even the TGD based model of mRNA-protein translation involves intentional aspects. Negative energy MEs are crucial for the understanding of the macro-temporal quantum coherence and have inspired the notions of remote metabolism and quantum credit card. The notion also leads to what might be called seesaw mechanism of energy metabolism, and allows to understand how micro-tubular surfaces provide dynamical records for the cellular sol-gel transitions and thus define fundamental micro-tubular representation of declarative long term memories.

The vision about dark matter hierarchy brings in perhaps the most decisive new elements.

1. Dark matter hierarchy leads to the identification of big leaps of evolution in terms of the emergence of new levels of dark matter hierarchy. Magnetic bodies are the intentional agents in this picture and it is possible to understand the control of logistics and declarative memory as basic functions associated with micro-tubules.

2. Synchronous neuron firing involves parallelization of microtubules. This coherent action can be understood in terms of macroscopic quantum coherence realized in terms of super-genes and the more general notion of multi-neuron with neurons organized to linear structures analogous to the lines of text on the pages of book defined by magnetic flux sheets.

3. Ca^{++} and Mg^{++} ions are known to be important for the depolymerization of microtubules and actin molecules occurring during nerve pulse. This conforms with the central role of the Bose-Einstein condensates of dark bosonic ions Ca^{++} and Mg^{++} and their exotically ionized counterparts in the generation of pulse in the proposed model, and more generally, in quantum bio-control based on charge entanglement between cell and magnetic body.

4. The ordered water associated with gel phase was earlier modelled in terms of dropping of protons to $k = 139$ space-time sheets. In the new framework this phase can be identified as a partially dark water. The response of cells to IR radiation is maximal at photon energy .1 eV. What makes bells ringing is that the model of high T_c conductivity based on dark matter hierarchy leads to the identification of the cell membrane as a Josephson junction generating ordinary IR photons with energy $2eV = .1$ eV at the membrane potential corresponding to threshold for nerve pulse generation kicking protons to $k = 139$ space-time sheet associated with ordered water.

This section was written much before the breakthrough induced by the model of DNA as tqc and the inspiration coming from the model of nerve pulse as acoustic soliton by Danish researchers [69]. Hence a lot is lacking and the contents of section are not necessarily completely consistent with the new vision. For instance, the phase transitions changing the value of $\hbar$ and tqc using 4-colored braids provide a general explanation for the selectivity of the catalytic action [L7]. I have however decided to leave the section as it is.

7.1 Dark matter hierarchy and big leaps in evolution

Dark matter hierarchy leads to an amazingly concrete picture about evolutionary hierarchy allowing to identify the counterparts for concepts like mineral, plant, and animal kingdom that we learned during schooldays and ceased to take seriously as students of theoretical physics as we learned that other sciences are just taxonomy. Even more, a view about what distinguishes between prokaryotes, eukaryotes, animal cells, neurons, EEG, and even about what makes cultural evolution, becomes possible. This view is also very useful when one tries to understand the role of microtubules.

There are two hierarchies involved with the dark matter hierarchy. The dark levels associated with weak bosons for which $k_W = 1$ corresponds to the p-adic length scale about $L_W(1) \sim 1$ Angstrom with exotic weak bosons corresponding to $k = 113$ (rather than $k = 89$ as for ordinary weak bosons). There is also electromagnetic dark hierarchy and in a given length scale one has $k_W = k_{em} + 2$. In a given scale weak sector would be ahead in evolution by two units so that weak dark bosons can be associated with more abstract functions like cognition and planning whereas em level would be related to simpler functions.

Ordinary matter corresponds to $k_W = k_{em} = 0$ and ordinary value of $\hbar$ and higher levels correspond to scaled up values of $\hbar$ with scalings λ^k, $\lambda \sim 2^{11}$. This mean scaling up of various quantum length scales and also the sizes of space-time sheets by λ. It seems that magnetic flux quanta are the primary structures forming hierarchy of this kind and large $\hbar$ means that cyclotron energy scales expressible as $E = \hbar(k)eB/m \propto \lambda$ so that an arbitrarily weak magnetic field strength can in principle correspond to a cyclotron energy above thermal threshold at room temperature.

The appearance of space-time sheets zoomed up in size by a power of λ means the emergence of new levels of structure and it is natural to identify big leaps in evolution in terms of scaling of $\hbar$ by λ and emergence of new large magnetic flux sheets satisfying magnetic flux quantization condition with the unit of flux scaled up by λ. This leap is quantum leap but in different sense as thought usually. The emergence of higher dark matter levels would basically mean the integration of existing structures to larger structures. A good metaphor are text lines at the pages of book formed by magnetic flux sheets whose width is scaled up by λ as the new level of dark matter hierarchy emerges.

This conceptual framework gives rather strong guidelines for the identification of the levels of evolutionary hierarchy in terms of dark matter hierarchy. The outcome is a detailed vision about big evolutionary leaps.

1. Molecular life

Magnetic body with $(k_W, k_{em}) = (1, 0)$ corresponds to the lowest level of hierarchy with the size of the basic structures corresponding to atomic length scale. The anomalous properties of water would be partly due to the presence of this level. At least the simplest bio-molecules regarded as living organisms would correspond to this level.

2. The emergence of prokaryotes as simplest membrane bounded structures

At $(k_W, k_{em}) = (2, 0)$ level high T_c superconductivity predicting the basic length scales characterizing the double layered cell membrane, the size scale of the cell, and the weak length scale $L_w(2) \simeq .3$ μm. Prokaryotic cells (bacteria, archea) without cell nucleus and other cell organelles would correspond to this level. Cell nuclei, mitochondria, and other membrane bounded cell nuclei would have evolved from prokaryotes in this framework. Also viruses and nannobacteria could correspond to this level of hierarchy. Cell membrane is responsible for metabolic functions and genome is scattered around the cell at this stage.

2. The emergence of cells having organelles

The appearance of magnetic bodies with $(k_W, k_{em}) = (3, 1)$ correlate with the emergence of simple eukaryotic cells, in particular plant cells. Cell nucleus would be the brain of the cell, mi-

tochondria would be the energy plant, and centrioles generating microtubules would define the logistic system. Also other organelles such as Golgi apparatus, ribosomes, lysosomes, endoplasmic reticulum, and vacuoles would be present. These organelles plus would form a symbiosis by topologically condensing to $(k_W, k_{em}) = (3, 1)$ magnetic body controlling their collective behavior. Centrosomes associated with animal cells would not be present yet but microtubule organizing centers would already be there.

The recent observations show that centrioles are not always in the characteristic T shaped conformation. Daughter centrioles resulting during the replication of mother centriole use first ours of their lifetime to roam around the cell before becoming mature to replicate. The interpretation would be that they are also life forms and magnetic body utilizes daughter centrioles to perform some control functions crucial for the future development of the cell. For instance, centrioles visit the place where axonal growth in neurons starts.

Cytoskeleton would act as a counterpart of a central nervous system besides being responsible for various logistic functions such as transfer of proteins along microtobuli. Centrioles give also rise to basal bodies and corresponding cilia/flagella used by simple cells to move or control movement of air or liquid past them. Cntriole pair would be also used by the magnetic body to control cell division.

The logistic functions are the most obvious functions of microtubules. Magnetic body would control cell membrane via signals sent through the cell nucleus and communicated to the cell membrane along microtubules. Basal bodies below the cell membrane and corresponding cilia/flagella would serve as motor organs making possible cell motion. Tubulin conformations representing bits would allow microtubule surface to represent the instructions of the magnetic body communicated via via cell nucleus to various proteins moving along the microtubular surface so that they could perform their functions.

TGD based view about long memory recall as communication with geometric past allows also the realization of cellular declarative memories in terms of the conformational patterns. Memory recall corresponds to a communication with geometric past using phase conjugate bosons with negative energies reflected back as positive energy bosons and thus representing an "image" of microtubular conformation just like ordinary reflected light represents ordinary physical object. This means that there is no need for static memory storage which in TGD framework would mean taking again and again a new copy of the same file.

Receptor proteins would communicate cell level sensory input to the magnetic body via MEs parallel to magnetic flux tubes connecting them to the magnetic body. We ourselves would be in an abstract sense fractally scaled up counterparts of receptor proteins and associated with dark matter iono-lito Josephson junction connecting the parts of magnetosphere below litosphere and above magnetosphere. The communication would be based on coherent photons and weak bosons of generalized EEG associate with the level of dark matter hierarchy in question. The mysterious bio-photons could be decay products of dark photons resulting via de-coherence meaning that the size of the dark photons is reduced in stepwise manner by factor $1/\lambda$ in single step.

3. The emergence of organs and animals

The emergence of magnetic bodies with $(k_W, k_{em}) = (4, 2)$ leads to the formation of multicellular animals. Magnetic body at this level gives rise to super-genome making possible genetic coding of organs not yet possessed by plant cells separated by walls from each other. The super structures formed from centrosomes and corresponding microtubules make possible complex patterns of motion requiring quantum coherence in the scale of organs as well as memories about them at the level of organs.

4. The emergence of nervous system

$(k_W, k_{em}) = (5, 3)$ magnetic body makes possible nervous system. The period of Josephson

oscillations associated with the scaled up variant of cell membrane is about 10 kHz and is consistent with the characteristic millisecond time scale of nerve pulse activity. Nerve pulse reception involves communication to the magnetic body via receptors of the neuronal membrane and the reaction of the magnetic body possibly generating a nerve pulse sequence. Charge entanglement made possible by W MEs makes possible nerve pulse generation as a quantum coherent process.

The emergence of the new level means also the integration of axonal microtobuli to text lines at the magnetic flux sheets making possible logistic control at the multineuronal level. The conformational patterns of the microtubular surface would code nerve pulse patterns to bit patterns representing declarative long term memories. An interesting question is whether the reverse coding occurs during memory recall.

5. The emergence of vertebrates and EEG

$(k_W, k_{em}) = (6, 4)$ magnetic body would bring in EEG possessed by vertebrates and also ZEG and WEG. Magnetic body is now of order Earth size. Natural time scale for the moment of sensory consciousness is measured as a fraction of second and basic building blocks of our sensory experience correspond to a fundamental period of .1 seconds.

6. Cultural evolution

Higher levels in the hierarchy would correspond mostly to the evolution of hyper-genome coding for culture and social structures. Introns are good candidate for the genes involved. The development of speech faculty is certainly a necessary prerequisite for this breakthrough.

7.2 Some TGD inspired new ideas about biochemistry

TGD provides several new physics concepts whose role in biochemistry is now relatively well understood thanks to the insights provided by the construction of the model of pre-biotic evolution [L4]. Hence there are hopes of understanding the basic principles of cellular control at macromolecular level, and to apply these principles to understand what happens during nerve pulse in the interior of neuron. It is not possible to overestimate the importance of the fact that p-adic length scale hypothesis makes the model quantitative and reduces the number of alternatives dramatically.

7.2.1 Increments of zero point kinetic energies as universal metabolic currencies

The protons and also various other ions and possibly even electrons liberate their zero point kinetic energy while dropping to larger space-time sheets. This process and its reversal define metabolism as a universal process present already during the pre-biotic evolution rather than as an outcome of a long molecular evolution [L4]. ATP-ADP transformation, polymerization by dehydration, and its reversal are key examples of the many-sheeted dynamics involving the dropping of protons from $k = 137$ space-time sheet liberating about .4-.5 eV of zero point kinetic energy and the reversal of this process. In TGD framework metabolism generalizes to a fractal metabolism involving a large number of metabolic currencies.

Negative energy MEs make possible remote metabolism realizing what might called quantum credit card. This makes energetic economy extremely flexible. F-actin polymerization [57] is an interesting application of this notion.

1. Each G-actin unit of F-actin is stabilized by Ca^{+2} ion and contains one ATP molecule. The polymerization of G-actin molecule is accompanied by an ATP-ADP transformation involving the dropping of a proton to a larger space-time sheet.

2. The fact that F-actin polymerization does not require energy [57] suggests that the zero point kinetic energy liberated in this manner is used to kick one proton to an atomic space-time sheet in G-actin molecule needed in dehydration inducing the polymerization.

3. This is achieved if the G-actin molecule emits a $.4-.5$ eV negative energy photon inducing the hopping of proton to an atomic space-time sheet associated with G-actin. The negative energy photon is received by the ATP molecule and induces the dropping of proton from atomic space-time sheet associated with the ATP molecule. This energetic seesaw could be controlled by a precisely targeted intentional action of the G-actin molecule by the generation of p-adic ME transformed then to negative energy ME. The seesaw mechanism can be generalized to a mechanism controlling the occurrence of sol-gel transitions.

A natural guess is that the emergence of larger space-time sheet with sizes characterized by p-adic length scales is a correlate for the evolution of more refined control and information processing structures utilizing smaller energy currencies. The situation is essentially quantal: the longer the length scale, the smaller the quantum of the metabolic energy. Micro-tubuli and other intracellular organelles represent excellent candidates for this kind of higher level metabolism refining the standard metabolism based on .4-.5 eV energy currency.

Since negative energy MEs with energies above thermal energy scale cannot induce transitions to lower energy states, a good guess is that negative energy MEs corresponding to metabolic currencies above the thermal energy $T_{room} \sim .03$ eV can be utilized for entanglement purposes. This is only a rough rule of thumb since the energy spectrum of systems at a given space-time sheet is expected to have an energy gap. Therefore negative energy MEs, even those below the ELF frequency range, are expected to be important.

Allowing n-ary p-adic length scales, this would mean in the case of hydrogen atom the upper upper bound $L(3,47)" = "L(141) = 2L(139)$ for the p-adic length scales in the hierarchy of water clusters. For electron the upper bound is cell membrane thickness $L(151) \simeq 10$ nm, which corresponds to the effective axonal electronic super-conductivity with the metabolic currency $.025 - .03$ eV. Interestingly, the water at room temperature contains flickering structures of size of order 20-30 nm with lifetime of order .1 ns [32]. MEs at energy $\simeq .03$ eV could stabilize these structures by kicking the dropped Cooper pairs back to k=151 space-time sheets. One can also ask whether micro-wave MEs at GHz frequency, perhaps generated in the rotational transitions of water molecules, modulate the generation of .03 eV MEs and are thus responsible for the flickering.

7.2.2 Liquid crystal phase of water as a stabilizer of biopolymers

The second key element is the understanding of the role of the liquid crystal [26] water in the stabilization of various bio-polymers. The reason is that the water molecules making possible depolymerization by hydration (also other means, say by the addition of heavy water or the increase of salt concentration, of reducing water activity have a stabilizing effect) are frozen to the liquid crystal. Thus the control at the level of bio-polymers could reduce to the control of whether cellular water is in sol or gel phase and to the understanding of what sol-gel difference means in the many-sheeted space-time.

Local gel-sol transitions could also provide a fundamental mechanism of cellular locomotion applied by, say, amoebae. Quite generally, various conformational changes needed in the cellular control are made possible by a local melting of the gel to sol followed by the conformational change in turn followed by a local sol-gel transition stabilizing the resulting conformation. The technological counterpart of this process is welding. The ME-controlled local melting and solidification of metals might in future technology make possible machines changing their structure routinely.

Local sol-gel transitions could also make possible the control of the conformations of the tubulin dimers expected to be sensitive to the di-electric constant of the water between the alpha and beta tubulin. This would mean that sol-gel phase transition and its reversal could define the bit of the declarative long term memory. Em MEs inducing gel-sol phase transition could provide a precisely targeted control of this kind. This would mean that coherent BE condensed photons associated with MEs could induce the sol-gel phase transition.

7.2.3 What distinguishes between sol and gel phases?

Sol-gel transition is crucial for the polymerization of actin molecules and micro-tubuli, and this dynamics probably involves something more refined than the molecular $k = 137$ metabolism. The dropping of protons/hydrogen atoms or of protonic Cooper pairs from $k = 139$ space-time sheet to larger space-time sheets is thus a unique candidate for what is involved with sol-gel transition.

The liberated zero point kinetic energy would be .1 eV for the dropping of proton or hydrogen atom (if .4 eV is the fundamental metabolic quantum whose value varies roughly in the range .4-.5 eV). For protonic Cooper pairs the energy would be .05 eV. According to the findings of Albrecht-Buehler [46], the response of cells to IR radiation at .1 eV photon energy is maximal.

The presence of protonic Bose-Einstein condensate at $k = 139$ space-time sheet might thus distinguish between the liquid-crystalline gel phase from sol phase. The particles of this effectively 2-dimensional liquid would be loosely bound tubular structures having a radius of about $L(139)$ and the BE condensate of the dropped proton would bind the water molecules to form this structure. Ordinary water would result when protons at $k = 139$ space-time sheet drop to larger space-time sheets. $k = 139$ space-time sheets would be also associated with small sized water clusters.

This phase could be interpreted in terms of the partially dark water whose existence is suggested by the empirical finding that the chemical formula of water seems to be $H_{1.5}O$ in attosecond scale in the sense that neutron diffraction and electron scattering see only 1.5 protons per oxygen molecule [62, 63, 64, 65]. As proposed in [F10], every fourth proton would be in $(k_W, k_{em}) = (1, 0)$ dark phase, the lowest dark matter phase and protons would form string like structure which could be regarded as scaled up nuclei consisting of protons (also ordinary nuclei correspond to nuclear strings in TGD framework and exotic $k = 127$ quarks play a key role in the model [F8]).

Attosecond suggests itself as the scale for the average time T_d spent by proton in dark phase in this case. In ordered water the lifetime of this phase might be considerably longer. If a dark variant of $k = 139$ space-time sheet is in question, T_d is scaled up by a factor λ^n, $\lambda \simeq 2^{11}$. Zero point kinetic energy and the energy of photons would remain invariant with photon wavelength scaled up by λ^n, making possible quantum coherent control in multi-neuron length scale.

7.2.4 IR radiation as a stabilizer of gel phase?

The model for the effective electronic super-conductivity generalizes to the case protonic Cooper pairs and ionic Bose Einstein condensates, and allows to develop a more precise picture. At the room temperature the thermal photons have energy lower than the zero point kinetic energy .1 eV so that the BE condensate can be maintained only by feeding IR photons kicking the hydrogen atoms back to $k = 139$ space-time sheet with a high enough rate. Therefore the stabilization of the gel phase requires an expenditure of metabolic energy. The simplest view is that in the ground state the entire interior of the cell is in gel phase so that the cell interior would have tonus analogous to muscular tonus.

By stopping the feed of the energy by IR photons to a particular region of cell, gel-sol transition with its various outcomes would occur spontaneously. A faster and energetically more economic manner to achieve the same outcome is to generate negative energy IR photons which induce the dropping of the hydrogen atoms from $k = 139$ space-time sheets. This mechanism also guarantees the stability of polymers by making hydration impossible. A more clumsy manner to guarantee this is to feed protons back to $k = 137$ space-time sheet where they induce dehydration: this process would probably cost much more energy.

Note that the gel-sol transition of the peripheral cytoskeleton assumed to occur during nerve pulse would rely on different different mechanism. Ca^{++} ions act as cross links between actin molecules and the lengthening of the cytoskeleton-membrane flux tubes in $\hbar$ increasing phase transition makes possible the flow of dark monovalent ions from cell exterior to peripheral cytoskeleton and induces gel-sol phase transition. This phase transition is initiated with the voltage over mem-

brane is reduced to very small value inducing quantum criticality. The proposal is that dark ionic currents from microtubules to axonal membrane induces this reduction.

One can of course ask whether the mere influx of monovalent ions is enough to induce the gel-sol phase transition in the required millisecond time scale. The reduction of cell potential to about .05 V, quite near to the value inducing action potential, implies that the photons of Josephson radiation have energy .05 eV. At this energy a resonant absorption of phase conjugate IR photons by the peripheral cytoskeleton inducing in turn the dropping protons to larger space-time sheet could induce the gel-sol transition.

7.2.5 Cell membrane Josephson junction as a generator IR coherent light

What is then the mechanism generating IR MEs acting as space-time correlates for coherent IR photons? The crucial observation is that the Josephson energy $E_J = ZeV$ for $Z = 2$ for cell membrane Josephson junction is .1 eV at threshold $V = 50$ mV for nerve pulse generation. The value of the metabolic energy quantum varies in certain range and the value .13 eV for the resting potential 65 mV would correspond to .052 eV metabolic quantum. Hence Josephson radiation could take care of kicking protons back to $k = 139$ space-time sheet thus stabilizing gel phase above the threshold for nerve pulse generation. The IR photons generated by Josephson current tend to propagate parallel to the axon and axon could act as a waveguide. When nerve pulse is generated at axonal hillock the frequencies of Josephson radiation are reduced below the threshold allowing stability of gel phase in region near axonal hillock and gel-sol transition should occur.

During nerve pulse the Josephson frequency varies in a wide range and has also negative values during the period when membrane voltage is positive (below 35 meV). A possible interpretation is that a phase conjugate IR radiation with energies $|E| < .07$ eV is generated. These photons could draw protons to large space-time sheet but with kinetic energy $E_0 - E$ rather than at rest.

The scaled up variants of IR photons at higher levels of dark matter hierarchy de-cohering into ordinary IR photons could make possible coherent quantum control in length scales given by $\lambda^n \times \lambda_{IR}$. For instance, EEG photons with frequency of about 5 Hz would correspond to the large $\hbar$ variants of IR photons with the same energy.

7.2.6 What happens in gel-sol phase transition?

The minimal model for the gel-sol transition could be following. When the membrane potential falls below the threshold value, Josephson radiation does not take anymore care of the stability of gel phase in the zone in the radiation zone directed parallel to the axon and gel-sol phase transition is generated in cellular water. The gel-sol transition occurs also at the level of micro-tubules and destabilizes them unless they take care of themselves by generating negative energy IR radiation received by cellular water. This might quite well occur.

7.2.7 How Ca^{+2} ions are involved with gel-sol phase transition?

Besides IR MEs also Ca^{+2} ions are involved with the gel-sol transition and if these ions act as cross links between proteins in gel, their role can be understood. Ca^{+2} waves are indeed known to be a fundamental cellular control mechanism. Ca^{+2} ions are known to induce a depolymerization of micro-tubules even in micro-molar concentrations whereas Mg^{+2} ions having much smaller ionic radius are known to favor the polymerization of the actin molecules [57]. Ca^{+2} ions which are more abundant in the cell exterior have a large ionic radius of order .099 nm whereas Mg^{+2} ions, which are abundant in the cell interior, have much smaller ionic radius. This supports the view that these ions have dual roles in cellular control.

As positive ions both Ca^{+2} and Mg^{+2} ions tend to increase the probability of the dropping of protons from the atomic $k = 139$ space-time sheets by repelling the protons from $k = 139$

space-time sheets to larger space-time sheets. This could mean gel-sol phase transition and the transformation of ordered water to ordinary water and the increase in the rate of depolymerization by hydration. On the other hand, both Ca^{+2} and Mg^{+2} tend to bind with themselves water molecules which lowers depolymerization rate. For Mg^{+2} with a small ionic radius the latter tendency wins: one can also say that Mg^{+2} is too small to act as a seed for depolymerization.

Bose-Einstein condensates of bosonic ions are key element of the proposed quantum control mechanism involving charge entanglement induced by W MEs connecting magnetic body and cell interior or exterior. The question is whether depolymerization involves the charge entanglement of Ca^{++} and Mg^{++} ions. One could argue whether the low amount of Ca^{++} (Mg^{++}) in cell interior (exterior) actually means that most of Ca^{++} (Mg^{++}) ions are in dark phase in cell interior (exterior). If so then at least sol-gel phase transition would be initiated by Josephson radiation and only at the later stages as Ca^{++} rush into neuronal interior Ca^{++} take the lead.

7.3 Nerve pulses and microtubules

As an application of above general view one can consider a model for what might happen during the nerve pulse inside axon and neuronal soma (this time interval can be as long as .5 seconds). The known pieces of information [57] indeed fit nicely with the above general principles and one ends up with the following scenario. Note again that this scenario has not been updated to correspond to the most recent view about nerve pulse.

7.3.1 Propagating sol-gel transitions as representations of declarative memories

The propagation of nerve pulse along axon means a propagation of gel-sol-gel phase transition along microtubule. Declarative long term memories could correspond to the temporal sequences of nerve pulses represented as propagating gel-sol-gel phase transitions. The representation of memories would be rather rough as compared to the capacity of microtubular conformations to represent bits: for a conduction velocity $v = 10$ m/s and duration of pulse about 1 ms single pulse would correspond to an axonal length of 10^{-5} meters meaning that 10^3 conformational bits would lumped to single bit. Dark matter hierarchy suggests the existence of a more precise representation at $k_{em} = 2$ level: the duration of the scaled down nerve pulse would be about .5 μs which for $v = 5$ m/s would correspond to a length 10 nm giving the size scale of tubulin dimer.

7.3.2 What happens inside neuron soma as nerve pulse is generated?

Consider first what could happen inside neuronal soma as nerve pulse is generated.

1. The positive energy Josephson radiation at IR frequency generated by cell membrane Josephson junction ceases temporarily and induces gel-sol transition in cellular water. Ca^{+2} ions flowing into the neuronal interior favor further the depolymerization of actin molecules. The micro-tubules of cytoskeleton receive the stabilizing IR radiation still from parts of neuronal membrane other than the throat of axon. They can also take care of themselves by sending phase conjugate IR radiation received by cellular ordered water.

2. The hydration of actin molecules in the vicinity of axonal hillock means that the activity of the water is reduced inside cell and water molecules from the cell exterior rush to the cell interior. The resulting swelling of the cell tears the positively charged ends of the micro-tubuli from the cell membrane. The micro-tubuli are now free to change their conformations and the micro-tubuli associated with different cells can arrange themselves in parallel configurations temporarily. Therefore they could act as quantum antennas generating coherent IR light needed to re-establish the gel phase very effectively: in an ideal case the power radiated is proportional to N^2, N the number of synchronously firing neurons. Also the return of

membrane potential to the resting value brings back the IR radiation stabilizing the gel phase.

3. Gel phase is re-generated. Actin molecules re-polymerize and micro-tubuli stick again to the cell membrane. Synaptic contacts and the distribution of the ionic channels in neuronal membrane are re-structured in the process and this means that learning occurs in the sense that cell begins to respond slightly differently to neuronal inputs. This does not correspond to conscious long term memories, which are represented as temporal conformational patterns of tubulin dimers. These memories are in the geometric past, and can change, and are re-experienced by sharing of mental images or communicating the memories classically as field patterns associated with MEs using memetic code.

4. Tubulin dimers are electrets and can be regarded as miniature capacitor plates containing 18 Ca^{+2} ions at the other plate and 18 electrons at the other plate [57, 50]. The average increments of the configuration space zero modes in the quantum jump sequence giving rise to the change of the conformation defines a two-valued geometric quale characterizing single bit of the long term memory. In [H8] a micro-tubular spatial cognitive code based on 13×13 bits is discussed. Temporal pattern extends this code to $13 \times 13 \times 126$ bit code.

7.4 Magnetic bodies, MEs and microtubules

It would seem that magnetic bodies are the intentional agents and the most natural assumption is that micro-tubuli are used by the magnetic body of cell for logistic purposes as well as to represent memories. First p-adic MEs representing the intention to suck energy and momentum from a particular part of the gel phase and transformed then to negative energy IR MEs by p-adic-to-real transition. Negative energy IR MEs would also serve as space-time correlates for the bound state quantum entanglement responsible for the generation of a multi-neuron macroscopic and -temporal quantum state.

Phase conjugate laser beams are the most plausible standard physics analogs for negative energy MEs and the coherent photons generated and Bose-Einstein condensates of photons contained by them. Since the energy .1 eV is above the range of the thermal energies, one can argue that negative energy photons can be absorbed only resonantly and thus very selectively. This view is supported by the demonstration of Feinberg showing that it is possible to see through chicken using phase conjugate laser beam [24].

Still an open question is whether laser beams actually correspond to dark photons having thus large value of $\hbar$ and scaled up wavelength. Scaled up wave lengths for .1 eV IR photons would be very natural concerning the control in length scales longer than that of single neuron and synchronous neuronal firing might involve the de-coherence of these dark photons to ordinary IR photons.

7.4.1 Could memes express themselves in terms of modulated IR radiation?

In TGD framework cell nucleus is the brain of the cell and acts as the fundamental controller of the cellular dynamics. Genetic expression is the slow part of this dynamics analogous to a rebuilding of the computer hardware. Software corresponds to memes, sequences of memetic codons realized as sequences of 21 DNA triplets in the intronic part of the DNA. Memetic codons would be the language with which the cellular programs are written. Super-genes or at least hyper-genes would naturally correspond to the sequences of memetic codons.

Memes could express themselves as temporal patterns of IR radiation amplified by micro-tubuli of length ~ 12.4 micrometers. Of course, in accordance with the fractality, also wavelengths corresponding to other metabolic currencies are probably realized. Single memetic codon carries 126 bits and single bit has a duration of about 1/1026 s, the basic time scale of the neuronal

dynamics. Both the frequency for the occurrence of sol gel transition and the duration of memetic codon in turn corresponds to 10 Hz frequency in alpha band, which suggests that $k_{em} = 4$ hierarchy level of dark matter hierarchy is involved with the periodically occurring sol-gel phase transition. The general framework would suggest that this phase transition occurs with this frequency only in vertebrate neurons.

These patterns of IR radiation at $\sim .1$ eV energy induce temporal sequences of sol-gel transitions representing memes physically. The beauty of MEs is that as topological field quanta of radiation they allow a precisely targeted local control not possible in Maxwellian electrodynamics. In particular, temporal sequences of micro-tubulin conformations could represent long term declarative memories expressed in a universal language using memetic codons as basic units.

7.4.2 Seesaw mechanism as a general manner to generate long term memories?

Micro-tubuli can act as quantum antennae producing IR photons by the dropping of proton Cooper pairs and amplified resonantly, when the micro-tubule has a length of about 12.4 micrometers. The absorption of these photons would in turn re-establish the gel phase in receiving system. This energetic gel-sol seesaw would be obviously ideal for the minimization of the dissipative losses.

The seesaw mechanism for the cellular control by micro-tubuli means that sol-gel transition in tubulin induces a gel-sol transition in the controlled part of the cell. Thus it would automatically construct micro-tubular declarative long term memory representation as a record about sol-gel transition history in various parts of the cell or cell substructure coded by the positions of tubulin dimers at the tubulin cylinder.

These dynamical maps about the active structures in the cell interior would be analogous to neuronal maps in cortex. If cell nucleus is the fundamental controller, also chromosomes might be seen as structures analogous to brain hemispheres forming dynamical sensory and motor maps about the interior of the cell. The static conformations would not represent memory bit. Rather, the changes of the conformations would represent the bit in accordance with the view that moments of consciousness correspond to quantum jumps between histories, and that the sequence of quantum jumps effectively integrates to a single quantum jump during macro-temporal quantum coherence.

8 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. It is now clear that mere Josephson currents are not enough: the breaking of super-conductivity due to leakage of supra currents from the super-conducting space-time sheets might also be an essential part of bio-control. A possible general conclusion is that Josephson currents are responsible for coordination whereas dissipative currents are related with the control aspect. The idea about charge entanglement made possible by W MEs and generating the dissipative currents makes this vision more precise.

One of the great ideas was that soliton sequences associated with the Josephson currents underly nerve pulse sequences. This idea turned out be be wrong as such: as a matter, soliton sequences would correspond to kHz resonance frequency and also EEG in the recent model and nerve pulses could be understood as a perturbation of this sequences. Since homeostasis as a many-sheeted ionic flow equilibrium involves also Josephson currents in an essential manner, it would be however light hearted to assume that Josephson currents and the dynamics at the level of cell membrane were totally uncorrelated. The model for sol-gel phase transition indeed demonstrates that Josephson currents generate IR photons crucial for stabilizing gel phase.

The frequency of the possible Josephson currents associated with the atomic space-time sheets of the cell membrane (or some larger space-time sheets with the same potential difference by the average many-sheeted ir-rotationality of the cell membrane electric field) corresponds in the resting state to a potential energy difference of about 65 meV so that the frequency is about 16 THz. It seems that the Josephson currents associated with the atomic space-time sheets define bio-rhythms in the molecular length and time scales.

This does not of course exclude the possibility that Josephson currents in ELF frequency scale are important. That this might be the case is suggested by the fact that the amplitude of the Josephson current does not depend on potential difference. These extremely small small potential differences, if present, must be between the space-time sheets representing relatively large bio-structures. One possibility is that pairs or parallel super-conducting magnetic flux tubes form Josephson junctions. Indeed, at the higher levels of dark matter hierarchy one obtains both time-like and space-like soliton sequences and their Lorentz boosts. At $k_{em} = 4$ level these waves are excellent candidates for the counterparts of standing and moving EEG waves. The recent model for nerve pulse indeed predicts also kHz synchrony and EEG as Josephson radiation: synchrony is in both cases an automatic prediction and follows from boundary conditions for soliton sequences.

What remained open in the earlier picture was the relationship between Josephson current circuitry and EEG, ZEG, and nerve pulse generation and the possible analogs of EEG, ZEG (and WEG) and nerve pulse generation in various other frequency scales. The discovery of generalized EWEG hierarchy associated with dark matter hierarchy lead to a general quantitative picture in this respect and allowed to interpret the components of generalized EEG in terms of cyclotron radiation and Josephson radiation as a response to cyclotron radiation. A fascinating possibility is that scaled up variants of nerve pulses with typical time scale of about 2 seconds instead of millisecond associated with say neuronal bi-layers are realized in higher vertebrates. At the next level the "nerve pulses" would have duration of order 1.1 hours.

Josephson currents suggest an important additional piece to the picture about of quantum control. Constructive 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.

It must be emphasized that detailed models cannot be taken too seriously. There are simply quite too many new physic mechanisms to be considered. The following considerations actually represent the first general vision about the role of super conductivity in living matter, and also this is a good reason for not taking them too literally. As in the case of other similar sections, I have made the decision to keep it as such since the general vision might apply also in the recent framework although it failed in the original model of nerve pulse and EEG. The replacement of the representation of Josephson junction by magnetic flux tubes carrying dark variants of electrons and ions might provide a general realization of the vision. For instance, standing wave solitons associated with the Josephson currents between cytoskeletal microtubules and regions of the cell membrane could be involved with DNA - cell membrane tqc. These currents - at least in the case of axons- might be also responsible for ordinary EEG (note that a hierarchy of fractal variants of EEG are predicted [M3].

8.1 Simple model for weakly coupled super conductors

Several kinds of Josephson currents between cell interior and exterior are possible. Solitons represent quantized Josephson currents which are large and able to facilitate the generation of nerve

pulse in the case of Na_+ and Ca_{++}. 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

$$\begin{aligned} D\Psi_1 &= m^2\Psi_1 + m_{12}^2\Psi_2 \ , \\ D\Psi_2 &= m^2\Psi_2 + m_{12}^2\Psi_1 \ , \\ D &= (\partial_\mu + iZeA_\mu)(\partial_\mu - iZeA_\mu) \end{aligned} \tag{19}$$

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. D denotes d'Alembert operator $\partial_t^2 - \nabla^2$.

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 assumption 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:

$$\Psi_i = \sqrt{n} exp(i\Phi_i) \ , \ i = 1, 2 \ . \tag{20}$$

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

$$\partial^\mu \left[\partial_\mu \Phi - q\Delta A_\mu\right] = m_{12}^2 sin(\Phi) \tag{21}$$

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

$$\partial_\mu A^\mu = 0 \tag{22}$$

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.

$$J_J = \partial_\mu J^\mu = Ze \times \frac{n}{m} \times m_{12}^2 sin(\Phi) \ . \tag{23}$$

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

$$J = Ze \times \frac{n2\pi Rd}{m} \times m_{12}^2 sin(\Phi) \ . \tag{24}$$

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

$$m_{12}^2 = \frac{1}{\Lambda^2} \ . \tag{25}$$

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

$$\begin{aligned} \partial_t \Phi &= ZeV(t,z) \ , \\ \partial_z \Phi &= ZeA_z(t,z) \ . \end{aligned} \tag{26}$$

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 the 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.

8.2 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[20].

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

$$\begin{aligned} D\Phi &= \epsilon \frac{1}{\Lambda^2}\Phi \ ; \\ D &= \partial_t^2 - \nabla^2 \ , \\ \epsilon &= -1 \ \text{ for } \ \Phi = n2\pi \ , \\ \epsilon &= 1 \ \text{ for } \ \Phi = (2n+1)\pi \ . \end{aligned} \tag{27}$$

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 un-stable 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), $\Phi \to \Phi + \pi$, which is exact symmetry of the 1+1-dimensional Sine-Gordon equation.

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

$$\begin{aligned} u &= \gamma_P(t - \frac{v_P z}{v^2}) \ , \quad \text{time like case} \\ u &= \gamma_P(z - v_P t) \ , \quad \text{space-like case} \\ \gamma_P &= \sqrt{\frac{1}{1-(\frac{v_P}{v})^2}} \ . \end{aligned} \tag{28}$$

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

$$\begin{aligned} \Omega &= \frac{\gamma_P v}{\Lambda} \ , \quad \text{time like case} \ , \\ \Omega &= \frac{\gamma_P v_P}{\Lambda} \ , \quad \text{space-like case} \ . \end{aligned} \tag{29}$$

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:

$$\frac{d^2\Phi}{du^2} = -\frac{1}{\Lambda^2} sin(\Phi) \ . \tag{30}$$

$u = vt$ 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

$$\frac{1}{2}v^2(\frac{d\Phi}{du})^2 + \frac{v^2}{\Lambda^2}\left[1 - cos(\Phi)\right] \;=\; K\frac{2v^2}{\Lambda^2} \;\; , \tag{31}$$

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

$$T \;=\; \frac{\lambda}{v} = \frac{\Lambda}{v}\int_{-\Phi_0}^{+\Phi_0} d\Phi \frac{1}{\sqrt{2\left[-cos(\Phi_0) + cos(\Phi)\right]}} \;\; . \tag{32}$$

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

$$T \;=\; \frac{\lambda}{v} = \frac{\Lambda}{v}\int_0^{2\pi} d\Phi \frac{1}{\sqrt{(\frac{d\Phi}{dt})^2(\Phi = \pi) + 2\left[1 - cos(\Phi)\right]}} \;\; . \tag{33}$$

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 [50], 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 [21]: could quantum groups have important applications in biology?

8.3 Are both time like and space-like soliton sequences possible ground states?

The model for the Josephson junction predicts the existence of both time like and space-like soliton sequences. Mathematician would expect that both ground states of coupled super conductors are realized in brain. The presence of space-like and time like modes could provide general insights to brain functioning and could relate to the fundamental dichotomies of brain consciousness.

8.3.1 The physical interpretation of time like ground states

Time like soliton sequences do not in general propagate and if they propagate, the phase velocity exceeds light velocity. The size of coherence region in the case of gap junction connected neurons can be rather large. Also micro-tubuli could form large coherent regions.

The time scales involved with the time like soliton sequence are however very fast, much faster that the time scales of EEG. This suggests that soliton sequences and oscillations are responsible for a synchronization in various scales defined by p-adic and dark matter hierarchies. There are intriguing analogies with right-left dichotomy of brain functioning and standing and propagating

EEG waves and one cannot exclude the possibility that the appearance of time like soliton sequences correlates with the emergence of standing EEG waves and synchronous firing whereas propagating space-like soliton sequences could accompany nerve pulse conduction. Standing soliton sequences could be associated with neuronal cell bodies and propagating soliton sequences with axons.

Oscillating and rotating time like waves could provide a general realization of biological clocks and facilitate the generation of macroscopic quantum systems. For instance, ordinary cells and glial cells could correspond to time like solitons. Also the gap junction connected neuron groups associated with primary sensory organs, various organs and brain could correspond to time like solitons.

For ordinary value of $\hbar$ the small oscillations for time like ground state have period of order 10^{-10} seconds: this follows solely from the spatial extension of nerve pulse of order $\Lambda \sim 10^{-2}$ meters and involves no assumptions about the detailed properties of the super conductor. These oscillations could coordinate protein dynamics. I do not know whether endoplasma membranes inside cells have resting potential: if not, they are good candidates for the carriers of time like ground states with oscillating voltage.

For cell membrane situation is different and the only possible interpretation is that the resting potential corresponds to the 10^{-13} second time scale determined by the membrane voltage and the mechanical analog is very rapidly rotating gravitational pendulum. At the higher levels of dark matter hierarchy the frequency is scaled down by a power of $1/\lambda \simeq 2^{-11}$, and $k_{em} = 4$ level would correspond to 5 Hz oscillation frequency if precise scaling holds true. These time-like solitons could indeed be interpreted as standing EEG waves whereas space-like solitons would correspond to propagating EEG waves. The presence of perturbations appearing at multiples of cyclotron frequencies of biologically important ions means that standing and moving waves at other frequencies are possible.

Glial cells [49] form a considerable fraction of cell population of brain are glial cells and are connected to each other by gap junctions, which can serve as Josephson junctions. In glial cells large amplitude oscillations with longer oscillation period could be present. The ciliar beating of monocellular animals [49] could be coordinated to coherent motion (making possible swimming of the monocellular organism) by the "EEG" waves.

Gap junctions between the nerve cells are not common but are encountered in the large coherently firing groups of nerve cells in the brain, in the sensory organs and other organs such as heart. The value of the parameter K is only slightly larger than the critical value $K = 1$ for EEG since the period of EEG oscillations is typically by a factor of order 10^8 longer than the period of small oscillations. The problem disappears when higher levels of dark matter hierarchy are allowed. Of course, if the potential difference in question corresponds to the membrane potential, one must have $K \gg 1$. One can wonder whether the criticality might have some deeper significance: perhaps phase transitions between EEG:s corresponding to rotating and oscillating gravitational penduli are possible.

8.3.2 Do the frequency scales of right and left brain EEGs differ by a factor 1/2?

The model for fractal hierarchy of EEGs [M3] suggests a deep difference between right and left brain hemispheres. Since the model makes the considerations in sequel more comprehensible it deserves to be reviewed.

1. The basic prediction is that quantum control from $k_{em} = 4$ magnetic body is carried out by using cyclotron radiation travelling along magnetic flux sheets traversing through DNA and containing genes very much like pages of book contain written text. Single text line contains genes from very many cells and even cells from different organisms.

2. Most biologically important bosonic ions have cyclotron frequencies f_c in alpha band of the strength of the endogenous magnetic field at flux sheets is $B = 2B_E/5$, $B_E = .5$ Gauss.

Sensory input to magnetic body comes from neuronal membrane at frequencies $nf_c \pm f_J$, $f_J = 5$ Hz. This means that theta and beta bands can be assigned to sensory input and can be regarded as satellites of alpha band representing the sensory response of cell membrane to the cyclotron radiation from magnetic body. $f_J = 5$ Hz for $Z = 2$ correspond to a fundamental "drum beat". Note that for $Z = 1$ (assignable to say exotic bosonic ions of type $I^{++,-}$, $I = Ca, Mg, Mn, ...$) one has $f_J = 2.5$ Hz.

3. The model explains the band structure of EEG and predicts correctly the narrow resonances at $3, 5, 7$ Hz and $13, 15, 17$ Hz [51]. Also the basic correlations between EEG and the state of consciousness can be understood, in particular why the chaotic character of beta band correlates with a state of strong concentration and high activity can be understood directly from the general expression of the Josephson current.

4. The difference between EEGs during wake-up and sleep can be understood if there are two classes of neurons such that the magnetic flux quantization condition $Ze \int BdS = n\hbar(k_{em})$ corresponds to $Z = 1$ for type I neurons $Z = 2$ for type II neurons so that the magnetic field strength assignable to flux sheets traversing DNA is B_E for type I and $B_E/2$ for type II. The key implication is that the cyclotron frequency scales differ by a factor $1/2$ so that the alpha bands would be around 10 Hz *resp.* 5 Hz for these two types of neurons. The first guess is that $Z = 1$ *resp.* $Z = 2$ correspond to neurons of right *resp.* left hemisphere. Left and right hemispheres could actually correspond to separate magnetic bodies with different field strengths.

   Also the value of $\hbar$ could be by a factor 2 larger for the right magnetic body so that also f_J would scale down by factor $1/2$. If also magnetic field for right magnetic body is weaker by a factor $1/2$, the area of of its flux quanta would is a factor 4 larger than for left magnetic body.

If the portions of brain corresponding to type I neurons falls first in sleep the control signals in alpha band and sensory input in beta and theta bands to the (corresponding) magnetic body disappear and only their scaled down variants remain. This explains why only theta and delta bands are present during sleep. Sleeping spindles can be understood as occasional wake-ups of type I regions. In the deepest stage of sleep only the cyclotron delta bands around 1 Hz and .5 Hz assignable to DNA cyclotron frequencies for type I and II neurons and having interpretation in terms of quantum control applied to DNA remain.

That at $k_{em} = 3$ level of hierarchy .5 Hz corresponds to kHz frequency of neuronal synchrony suggests that $k_{em} = 3$ magnetic bodies are in deep sleep during neuronal synchrony. In a similar manner deep sleep at our level would correspond to the analog of neuronal synchrony at higher level corresponding perhaps to the analogs of nerve pulse patterns assignable to double neuron layers and characterized by a time scale of 2 seconds instead of millisecond. The analog of type I (II) alpha band would correspond to a time scale of 200 (400) seconds and might define a detectable biorhythm.

8.3.3 Left/right $\leftrightarrow$ space-like/time like?

It has been already proposed that space-like/time-like dichotomy most naturally corresponds to axon-neuron body dichotomy. One can however consider also alternative possibilities. The difference of EEG frequency scales (if assignable to left-right dichotomy) need not be the only difference between the EEGs of right and left hemispheres. If there is a correlation between the character of EEG waves and that of solitons sequences at $k_{em} = 4$ level of dark hierarchy, the difference between left and right brain could indeed reflect the differences between space-like propagating space-like soliton sequences and non-propagating time like soliton sequences. Only dominance

would be in question, both modes would appear certain fraction of time in both brain hemispheres (recall that millisecond is the natural unit of time and 10^{39} quantum jumps occurs during one second). Propagating soliton sequences could give rise to a relatively large number of sub-selves (mental images) corresponding geometrically to linear brain circuits and representing linear and temporal aspects of cognition (speech and thought). 'Boolean' mind represented by sequences of cognitive neutrino pairs might be possible only in this mode[1]. Time like soliton sequences would be associated with relatively few and large spatial regions representing selves. This would give rise to a parallel processing of information.

An interesting question is whether epileptic seizures could involve non-propagating EEG of anomalously high amplitude. Also meditative states and 'whole-body consciousness' might involve non-propagating EEG: the basic procedure for achieving meditative states is emptying of mind from all possible mental images which means formation of large sub-selves represented by brain regions with time like EEG. The identification of the dominance of standing EEG waves with this kind of mental states is consistent with the absence of sensory consciousness. The low level of motor activity suggests that the standing EEG waves produced by time like soliton sequences are not responsible for motor control.

8.4 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 corresponds to quantum control. More precisely, the non-dissipative Josephson currents associated with weakly coupled super conductors would be the key element in coordination whereas resonant dissipative currents between weakly coupled super conductors would make possible quantum 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 [48]. 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 the case of the vertebrates the generation of somites is a very regular process starting at certain phase of development and proceeding with a clockwise precision.

8.4.1 Homeostasis as many-sheeted ionic flow equilibrium

The experimental work of Ling, Sachs and Qin [34, 39] and other pioneers [40, 47] challenges the notions of ionic channels and pumps central to the standard cell biology. Ling has demonstrated that the ionic concentrations of a metabolically deprived cell are not changed at all: this challenges the notion of cell membrane ionic pumps. The work of Sachs and Qin and others based on patch-clamp technique shows that the quantal ionic currents through cell membrane remain essentially as such when the membrane is replaced by a silicon rubber membrane or by a cell membrane purified from channel proteins! this challenges the notion of cell membrane ionic channels. A further puzzling observation is much more mundane: ordinary hamburger contains roughly 80 per cent of water and is thus like a wet sponge: why it is so difficult to get the water out of it?

[1] See the chapter "Genes and memes".

These puzzling observations can be understood if the homeostasis of cell and its exterior is regarded as an ionic flow equilibrium in the many-sheeted space-time. Ionic super currents from super-conducting controlling space-time sheets flow to controlled atomic space-time sheets and back. Currents are of course ohmic at the atomic space-time sheets. One can understand how extremely small ionic densities and super currents at cellular space-time sheets can control ionic currents and much higher ionic densities at atomic space-time sheets. Immense savings in metabolic energy are achieved if the ohmic currents at the atomic space-time sheets flow through the cell membrane region containing the strong electric field along super-conducting cell membrane space-time sheet (rather than atomic space-time sheets) as a non-dissipative supra current. This clever energy saving trick makes also the notion of ionic channels obsolete for weak ionic currents at least.

Super-conducting space-time sheets contain a plan of the bio-system coded to ion densities and magnetic quantum numbers characterizing the super currents. Bio-control by em fields affects these super currents and one can understand the effects of ELF em fields on bio-system in this framework. The model relies crucially on the liquid crystal property of bio-matter (hamburger mystery!) making possible ohmic current circuitry at the atomic space-time sheets as a part of the many-sheeted control circuitry. There is a considerable evidence for this current circuitry, Becker is one of the pioneers in the field [61]: among other things the circuitry could explain how acupuncture works.

8.4.2 Quantum model for pattern recognition

Time translation invariant pattern recognition circuit can be realized by using two coupled super-conductors. The first super-conductor contains the reference supra current and second super-conductor contains the supra current determined by the sensory input. Supra currents are assumed to have same spatially and temporally constant intensity. If the supra currents have spatially constant phase difference, also Josephson currents are in the same phase and sum up to a large current facilitating synchronous firing. The temporal phase difference of supra currents does not matter since it affects only the overall phase of the Josephson current. Therefore patterns differing by time translations are treated as equivalent. Quite generally, the requirement of time translational invariance, favors the coding of the sensory qualia to transition frequencies.

The destructive interference of supra currents provides an tool of pattern cognition in situations when the precise timing is important. The pattern to be recognized can be represented as a reference current pattern in some neuronal circuit. Input pattern determined by sensory input in turn is represented by supra current interfering with the reference current. If interference is destructive, synchronous generation of nerve pulses in the circuit occurs and leads to a conscious pattern recognition. Obviously the loss of time translation invariance makes this mechanism undesirable in the situations in which the precise timing of the sensory input does not matter. One can however imagine situations when timing is important: for instance, the deduction of the direction of the object of the auditory field from the phase difference associated with signals entering into right and left ears could correspond to this kind of situation.

In both cases one can worry about the regeneration of reference currents. The paradigm of four-dimensional quantum brain suggests that sensory input leads by self-organization to a stationary spatial patterns of supra-currents and this process depends only very mildly on initial values. Thus self-organization would generate automatically pattern recognizers.

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

Weakly coupled super conductors and auantum 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 [29]

$$\begin{aligned} J &= J_0 sin(\Delta\Phi) = J_0 sin(\Omega t) \ , \\ \Omega &= ZeV \ , \end{aligned} \tag{34}$$

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 [29]

$$J_0 = \frac{\pi}{2e}\frac{\sigma_s \Delta}{d} \ . \tag{35}$$

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

$$J = \sum_n J_0(n) sin(\Omega t + \Delta\Phi(n)) \ . \tag{36}$$

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 un-stability of the structure. When the supra current in the circuit dissipates below a critical value, un-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[30, 29]. 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 a un-stability 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 un-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.

8.4.4 How MEs could generate soliton sequences?

MEs could as bio-controllers using the same general mechanism which underlies remote mental interactions and this aspect of bio-control could be seen as endogenous remote mental interactions between cells and other parts of organism. Pairs of low and high frequency MEs are involved. Low frequency MEs, say EEG MEs, serve as correlates for quantum entanglement between body parts: already this is enough for remote viewing regarded as sharing of mental images by fusion of mental images. The psychokinesis aspect is possible by high frequency MEs propagating like massless particles inside low frequency MEs. These MEs induce bridges and thus leakage of ions between various space-time sheets at the receiving end. This means self-organization by dissipation.

MEs can also act as Josephson junctions connecting super-conducting space-time sheet characterized by p-adic primes which can be different. This kind of Josephson junction contains the em field associated with ME as an external field and the mathematical description of this coupling follows from the model for the coupling of electromagnetic field to super conducting order parameters. In Minkowski coordinates the modification of the Sine-Gordon equation is simple:

$$\partial^\mu \left[\partial_\mu \Phi - Ze\Delta A_\mu\right] \quad = \quad m_{12}^2 sin(\Phi) \ . \tag{37}$$

Here Φ denotes the phase difference over the Josephson junction, which is idealized with a continuous Josephson junction, and actually is a continuous Josephson junction in the case of ME. ΔA_μ denotes the difference of the vector potential over the junction.

The coupling to the vector potential can in the lowest order described by the condition

$$\partial_\mu \Phi_0 = Ze\Delta A_\mu$$

assumed to hold for a maximal number of components of vector potential. Here of course integrability conditions pose restrictions. One can develop perturbation series for Φ by substituting Φ_0 to the right hand side and calculating Φ_1 using the right hand side as a source term, and so on.

If the transversal em field associated with ME contains time independent radial electric field this gives rise to a constant potential term giving rise to a generation of soliton sequences. The period Ω of rotation for the soliton satisfies $\Omega = eV$, where eV corresponds to the potential difference defined by the constant part of the electric field of ME. It can also happen that ME contains only the oscillatory electromagnetic field: if the frequency is same as the frequency associated with small oscillations of the Sine-Gordon pendulum a resonant coupling is expected to result. In this case the frequency is in radio frequency range.

Also noise is present and it is quite possible that the noise provides the energy needed to amplify the weak periodic signal provided by ME to a soliton sequence by stochastic resonance. The mechanism is discussed in detail in the chapter "Quantum model for EEG and nerve pulse". This suggests that MEs could basically control small very fast oscillations of the membrane potential.

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