Quantum Theory of Self-Organization

M. Pitkänen[1], February 1, 2006

[1] Department of Physical Sciences, High Energy Physics Division,
PL 64, FIN-00014, University of Helsinki, Finland.
matpitka@rock.helsinki.fi, http://www.physics.helsinki.fi/∼matpitka/.
Recent address: Puutarhurinkatu 10,10960, Hanko, Finland.

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Abstract

Quantum theory of self-organization based on the idea that quantum jump serves as the basic step of self-organization, is represented. The notion of self and the identification of self as the fundamental statistical ensemble gives totally new meaning for the concept of self-organization as a generation of hierarchies of selves. Zero modes of the configuration space geometry, whose existence derives from the generalization of point like particle to 3-surface, provide universal, nonlocal order parameters and the emergence of the new level of self-organization occurs through phase transition like process as also in Haken's theory. The fact that quantum jumps involve localization in zero modes means that the sequence of quantum jumps means hopping in zero modes characterizing the classical aspects of the spacetime geometry. The quantum version of Haken's theory of self-organization is proposed and is almost identical with Haken's theory. Spin glass analogy means that "energy" landscape has fractal valleys inside valleys structure: this structure is important for understanding long term memories. A crucially important aspect of the quantum self-organization is the Darwinian selection of very few asymptotic self-organization pattterns by dissipation which explains the selection of both genes and memes: this selection provides royal road to the understanding of various miraculous feats performed by living matter. The comparison with Rupert Sheldrake's concepts of morphic field and morphic resonance leads to interesting ideas about how learning at the level of species could occur quantum-mechanically. For instance, the phenomenon of biofeedback suggests that self could quite generally effectively act as morphic field for its subselves. If entanglement occurs mostly between subsystems having same value of p-adic prime one could understand the "alike likes alike" rule of Sheldrake at the quantum level.

1 Introduction

Self-organization [20] seems to be closely related to the generation of fractal patterns and the book of Barnsley [16] about fractals gives rather convincing arguments supporting the belief that a very general class of fractals can be regarded as *fixed points of iteration*. The space in which fixed point exists is rather abstract: typically it belongs to the set of subsets of some space, say, 3-dimensional Euclidian space. This fixed point can be a landscape, biosystem, ecological population, hydrodynamical flow,... For instance, the success of this receipe in reproducing even a virtual photo of a forest is amazing. Even evolution could be regarded as resulting from this kind of iterative process leading gradually to a fixed point.

One can even consider the possibility that iteration, if understood in a sufficiently general sense, could be the basic element of self-organization. There is no obvious manner how this iteration could result from the equations of the classical physics. For instance, Haken has been ready to consider the possibility that subsystems, even electron, are actually certain kind of computers, cellular automata and that the basic computational step would provide the required fundamental iteration step.

TGD suggests that the quantum jump between quantum histories could be the fundamental iteration step! Even more, self-organization has a completely new meaning in TGD. Self-organization means evolution of the hierarchical structures formed by conscious selves! In TGD subjective time evolution corresponds to the sequence of quantum jumps $\Psi_i \to U\Psi_i \to \Psi_f$, where U is the TGD counterpart of the time evolution operator $U(-t,t)$, $t \to \infty$, associated with the scattering solutions of Schrödinger equation. It seems however uncessary and probably also impossible to assign any real Scrödinger time evolution with U. Psychological time and its arrow can be understood and simple arguments suggest that single quantum jump corresponds to an average increment of psychological time, which is of order CP_2 time about 10^4 Planck times. Quantum jump decomposes to quantum jumps performed by separate selves with self being defined as subsystem able to remain p-adically unentangled during sequential quantum jumps. Quantum jump corresponds to the measurement of density matrix for some subsystem of self (or equivalently, for its complement

inside self). Each quantum jump involves localization in zero modes as well as a localization to a definite sector D_p of configuration space of 3-surfaces. This means that the final states of quantum jumps are superpositions of macroscopically equivalent space-time surfaces: hence the classicality of the world of the subjective experience.

Negentropy Maximization Principle (NMP) tells that in a given quantum state only one of the most quantum entangled subsystems can perform the quantum jump. The reduction of the entanglement entropy in the quantum jump is as large as possible: presumably the interpretation of entanglement entropy as some kind of information gain makes sense [H7]. Quantum jumps inside self imply dissipation crucial for self organization and quantum jump could be regarded as the basic step of iteration process. If self consists of a large number of nearly identical subselves, quantum statistical determinism implies that quantum jump can be interpreted as iterated map from the point of view of self. From the point of view of entire Universe this is certainly the case. NMP predicts that self organization and hence presumably also fractalization can occur inside selves.

NMP allows two kinds of quantum jumps to occur inside irreducible self (self having no decomposition into smaller selves). Quantum jump can reduce the entanglement between material and mind like space-time sheets or between two matter+mind type subsystems in which case two candidates for new subselves are generated. A candidate for new subself can be generated also spontaneously when U generates vanishing p-adic entanglement for some subsystem.

The basic hypothesis is that the experiences of self after wake-up sum up to single experience: this makes self extended object with respect to subjective time. The assumption that this sum of experiences involves kind of averaging guarantees that the sensory experiences are reliable despite the fact that quantum nondeterminism is involved with each quantum jump. Thus the measurement of density matrix in general corresponds to the passive aspects of consciousness such as sensory experiencing. The choice between different degenerate absolute minima of the Kähler action is interpreted as giving rise to volition and hence to the active aspect of consciousness. In this picture one can understand the fundamental perception-reaction feedback loop of biosystems as resulting from the combination of the active and passive aspects of consciousness.

TGD indeed gives good hopes for understanding self-organization using quantum level concepts.

1. Quantum criticality of TGD suggests the existence of macroscopic quantum systems in all length scales so that quantum theory of self-organization might apply also in the description of the hydrodynamical self-organization!

2. By generalized unitarity conditions (and also by NMP) each quantum jump must involve localization in sector D_p of configuration space with effective topology determined by R_p. This means that the sequence of quantum jumps corresponds to a sequence of p-adic primes p. Simple geometric argument suggests that p must increase in long run. Also NMP favours the increase of p and implies evolution and second law of thermodynamics since maximum entanglement entropy equal to maximum negentropy gain in quantum jump increases with p.

3. The replacement of the point like particle with 3-surface brings in an infinite number of zero modes characterizing the shape and size of and the classical Kähler field (essentially the classical electromagnetic field under rather general assumptions) associated with the 3-surface. Even macroscopic 3-surfaces behave like elementary particles in these degrees of freedom. These zero modes serve as fundamental order parameters, which in the ordinary theories of self-organization must be introduced in an ad hoc manner. As already noticed, localization in zero modes implies that the world of conscious experience looks classical and that time evolution in zero modes can be regarded as hopping like motion.

4. Long range quantum correlations are crucial for quantum self-organization and are indeed possible in these new degrees of freedom. Quantum criticality implies also fractality. The universality of $1/f$ noise, which is a direct consequence of criticality, is difficult to understand in standard physics context since critical systems are by definition unstable. Therefore the universality of $1/f$ noise can be regarded as a direct support for quantum criticality of the entire Universe! From the real point of view self itself is critical phenomenon since vanishing p-adic entanglement corresponds to subcritical real entanglement with critical entanglement defined by the unique pinary cutoff associated with the mapping of the real geometric structures to their p-adic counterparts.

5. Arbitrarily large join along boundaries condensates of 3-surfaces are possible by quantum criticality and this suggests the possibility of arbitrarily large macroscopic quantum subsystems. Especially interesting biological examples of join along boundaries bonds are chemical bonds, the MAPs connecting microtubules and gap junctions connecting cells. Join along boundaries bonds can also join mindlike space-time sheets.

6. The manysheeted space-time concept having hierarchical structure provides the realization of a fundamental slaving hierarchy at the level of the space-time geometry. p-Adic length scale hypothesis makes this hypothesis quantitative.

7. Spin glass analogy leads to an infinite-dimensional generalization of Thom's catastrophe theory and the maxima of Kähler function play the role of the minima of the potential function in Haken's theory of self-organization. Vacuum functional of TGD in turn is in the role of the generalized partition function appearing in Haken's theory.

8. Dissipation can be understood as caused by quantum jumps and occurs only inside selves. Dissipation leads to Darwinian selection of the asymptotic self-organization patterns and the selection of both genes and memes, in particular stable mental images, can be understood as resulting from quantum self-organization. Note that dissipation can be regarded as a direct signature of consciousness.

This picture allows to generalize Haken's classical theory of self-organization to quantum context. The sequence of quantum jumps can be regarded as hopping in zero modes and hence situation is very classical, in fact much like in Brownian motion. In particular, the classical theory of the feature detection generalizes to quantum context. One can also generalize Haken's theory to describe how biosystem acts to external world; in this theory the active quantum jumps play the key role. Rupert Sheldrake [21] postulates the concept of morphic fields and morphic resonance making possible learning and memory at the level of species and it is interesting to find whether TGD based theory of self-organization provides support for Sheldrake's ideas.

2 Quantum theory of self-organization

2.1 Basic characteristics of self-organization

Self organizing system corresponds typically to a system dissipating the energy feeded into it. Dissipation leads to typical self-organization patters decomposing into more or less autonomous subsystems. Subsystems perceive the state of the external world and reacts to it. Human society is a typical example in which individuals or groups of them perceive and react. Self-organization is also critical phenomenon in the sense that new self-organization patterns are formed in phase transition like manner at the critical values of the parameters characterizing the interaction of the system with external world. Co-operatitivity, long range correlations and fractality, typical characteristics of critical phenomena, are involved with the emergence of new self-organization

patters. Also spontaneous symmetry breaking associated with the phase transitions changing self-organization pattern is a characteristic of self-organization process.

Iteration, understood in a very general sense, seems to be the basic element of self-organization. A good example is provided by cellular automata (game of life is the best known example). Automaton consists of cells, which perceive their surroundings and perform a decision to change their state according to some rule. Rule need not be deterministic but the dynamics dictated by it is irreversible. This is what makes it so difficult to understand how iteration might result from the reversible equations of physics and suggests that thermodynamics or some deeper principle behind thermodynamics is important.

Second example is camera, which monitors tv screen to which the picture taken by the camera is the feedback. This system exhibits typical self-organization patterns obtained by varying the direction angle of the camera with respect to the TV screen. Iteration is rather abstract process now: camera perceives the state of tv and reacts by sending a new picture to the TV screen.

Benard convection is a third standard example of self-organization. When liquid is heated evenly from below, a temperature gradient develops and at some critical value of temperature gradient, convection sets on. A flow pattern consisting of liquid cells is formed. The size and shape of cell as well as the pattern of liquid motion in cell depends on the parameters characterizing the situation (size and shape of the liquid vessel, the temperature difference,...). As temperature difference increases, more complicated flow patterns emerge: what happens is essentially that patterns of larger scale coherent motions emerge by the organization of the Benard cells to larger units.

Biosystems provide more complicated examples of self-organization. In this case self-organization has many hierarchical levels. First DNA and proteins together with genetic code are formed by self-organization at molecular level, then come monocellulars, multicellulars,..., individuals, families, social organizations,... Clearly, subsystems of previous level form combine to form larger coherent subsystems at the higher levels of self-organization.

Iteration is clearly a 'social' process: subsystem perceives consciously the external world and reacts to it. Subsystem can in principle be any subsystem of the entire system so that the scenario is considerably more general than cellular automaton. The process can also create a subsystem such as Benard cell in Benard convection or a cell in biological evolution.

2.2 Self-organization as organization of self-hierarchies

TGD suggests that the quantum jump between quantum histories could be the fundamental iteration step of self-organinization! Even more, self-organization has a completely new meaning in TGD. Self-organization can be identified as the evolution of hierarchical structures formed by conscious selves.

2.2.1 Quantum jump as the basic iterative step of self-organization

In TGD subjective time evolution corresponds to the sequence of quantum jumps

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

where U represents unitary quantum mechanical "time evolution".

Quantum jump corresponds to the measurement of density matrix for some subsystem of self (or equivalently, for its complement inside self). The requirement that quantum jumps corresponds reduces to quantum measurement in quantum field theoretic sense implies that each quantum jump involves localization in zero modes so that time evolution by quantum jumps can be regarded as hopping in zero modes. Generalized unitarity based on the generalization of S-matrix concept such that S-matrix decomposes to a collection of p-adic valued S-matrices implies localization to a

definite sector D_p of configuration space of 3-surfaces obeying p-adic effective topology. This means that the final states of quantum jumps are superpositions of macroscopically equivalent space-time surfaces: hence the classicality of the world of the subjective experience. Hence quantum jump occurs also between two classical histories, say a between solutions of reversible equations of hydrodynamics in Benard convection.

2.2.2 Autonomous subsystems of self-organized system as selves

Crucial concept is that of self being defined as subsystem able to remain p-adically unentangled during sequential quantum jumps. In real context self is critical system in the sense that self exists only provided real entanglement entropy is below the value determined by the unique pinary cutoff associated with the so called phase preserving canonical identification mapping real geometric structures to their p-adic counterparts. Since self behaves effectively like separate autonomous universe, an attractive hypothesis is that the typical decomposition of self-organized system to almost autonomous subsystems corresponds to the decomposition of universe to selves. This means very close connection between self-organization theory and theory of consciousness.

Quantum jump decomposes to quantum jumps performed by separate selves. Negentropy Maximization Principle (NMP) tells that in a given quantum state only one of the most quantum entangled subsystems can perform the quantum jump. The reduction of the entanglement entropy in the quantum jump is as large as possible: presumably the interpretation of entanglement entropy as some kind of information gain makes sense (for the definition of information gain of conscious experience [H7]. Quantum jumps inside self imply dissipation crucial for self organization. If self consists of a large number of nearly identical subselves, quantum statistical determinism implies that quantum jump can be interpreted as iterated map from the point of view of self. From the point of view of entire Universe this is certainly the case. NMP predicts that self organization and hence presumably also fractalization can occur inside selves.

NMP allows two kinds of quantum jumps to occur inside irreducible self (self having no decomposition into smaller selves). Quantum jump can reduce the entanglement between material and mind like space-time sheets or between two matter+mind type subsystems in which case two candidates for new subselves are generated. A candidate for new subself can be generated also spontaneously when U generates vanishing p-adic entanglement for some subsystem.

The basic hypothesis is that the experiences of self after wake-up sum up to single experience: this makes self extended object with respect to subjective time. The assumption that this sum of experiences involves kind of averaging guarantees that the sensory experiences are reliable despite the fact that quantum nondeterminism is involved with each quantum jump. Thus the measurement of density matrix in general corresponds to the passive aspects of consciousness such as sensory experiencing. The choice between different degenerate absolute minima of the Kähler action is interpreted as giving rise to volition and hence to the active aspect of consciousness. In this picture one can understand the fundamental perception-reaction feedback loop of biosystems as resulting from the combination of the active and passive aspects of consciousness.

Second hypothesis is that self that the experience of self X is 'sum' of the experiences of its subselves X_i abstracted so that some kind of average over the experiences $\langle X_{ij} \rangle$ over sub-subselves is formed. This means that the self hierarchy gives rise to infinite hierarchy of abstractions. The hierarchy of selves corresponds geometrically the hierarchy of space-time sheets and is an obvious counterpart for the nested slaving hierarchy of self-organized systems with the property that the system at given level of hierarchy serves as a master for the lower level systems inside it.

Although active quantum jump itself is nondeterministic, quantum statistical determinism implies that time evolution by quantum jumps is predictable at the limit of large self having large number of subselves. In this quantum evolution is genuinely iterative process in the space of distribution functions for various types of selves. However, at the level of the large sub-selves there is always non-predictability involved. This feature could make it possible to understand the special

features of biological self-organization. A good example is the behavior of group of people who meet for the first time: self-organization leads rapidly to an adoption of simple social roles. In this kind of self organization both active and passive quantum jumps play important role.

2.3 Dissipation and quantum jumps between histories concept

The phenomenon of dissipation is paradoxical from the point of view of standard physics. It is generally accepted that fundamental laws of physics are reversible but everyday reality is manifestly irreversible. Thus the situation is rather schizophrenic. Two worlds, the reversible and extremely beautiful world of fundamental physics and the irreversible and mathematically rather ugly 'real' world, seem to exist simultaneously. The description of dissipation is highly phenomenological: one introduces mathematical monsters like non-Hermitian Hamiltonians; in particle physics particle decay widths are introduced by making energies complex; in macroscopic length scales one introduces parameters like friction coefficients, viscosity, diffusion constants, etc.. The mathematical beauty of the reversible world is lost and dissipation becomes an unavoidable nuisance of physics, which perhaps explains why so little conscious thought is devoted in the attempts to understand why these two worlds seem to co-exist.

This schizophrenic world picture is of course logically inconsistent. Something in the implicit assumptions underlying this paradoxical world view must be wrong. Quantum jump between quantum histories concept indeed resolves the paradox and explains the apparent existence of two worlds as resulting from a wrong view about psychological time. Without quantum jumps there would be single reversible reality behaving determistically and there would be neither dissipation nor consciousness. Quantum jumps between the reversible realities however cause dissipation, which can be more correctly seen as a self organization via quantum jumps and as a necessary prequisite for evolution and consciousness. The source of all the ugly mathematics related to the description of dissipation is the failure to realize that there are two time developments: subjective time development proceeding via quantum jumps and geometric time development described by the dynamical equations without dissipation. The ugly dissipative terms in dynamical equations result, when the sequence of quantum jumps between time developments is replaced with single dissipative time development. One can very loosely say that the dissipative world is envelope for the classical worlds, one classical world per CP_2 time. Or more concretely, dissipative space-time surface is the space-time surface going through a sequence of 3-surfaces defined by the values of psychological time measured using CP_2 time as unit.

Dissipation can be seen as a phenomenological description for the tendency of the self-organizing development by quantum jumps to lead to fixed points, limit cycles, limiting tori, strange attractors, etc.. in the space of quantum histories. In this description irreversible time development is 'almost' envelope for the family of reversible time developments defined by quantum jumps: various parameters characterizing dissipation describe the deviation from the exact 'envelopeness'. Hence the study of chaotic dissipative systems could be also seen as a study of the phenomenological descriptions for the asymptotic behaviors yielded by the time development by quantum jumps. It is not of course clear whether this kind of effective description really works always or whether one should replace it by a genuine quantum description under some circumstances.

Consider as an example the description of a self organizing system using Haken's theory of self-organization relying on the hypothesis that system's states correspond to the minima of free energy function. Free energy depends on external parameters. When the value of some external parameter becomes critical, large fluctuations in long length scales occur and new level of self-organization with new length scale emerges or disappears in a phase transition like manner. For instance, potential well can split into two potential wells and system selects either well. This suggests that near the critical values of the external parameters quantum statistical determinism and hence also effective description fails at macroscopic length scales. The catastrophic changes in

system's behavior could correspond to macroscopic quantum jumps. Biosystems obviously provide excellent candidates for critical systems. Since TGD Universe is quantum critical, any subsystem is basically critical system: only the time scale of the critical fluctuations determines whether given system looks critical from human point of view. In particular, selves are critical systems since the increase of the real entanglement above critical value means disappearance of self. Since time development corresponds to hopping in zero modes which are the fundamental order parameters in TGD framework, the picture of Haken applies almost as such as far as development in zero modes is considered. An interesting question is whether the criticality in zero modes actually corresponds criticality for disappearance or occurrence of new self.

Dissipation can be seen as an extremely concrete proof for the hypothesis that quantum jumps between quantum histories occur all the time. However, to possibly convince colleagues about this, very delicate experiments must be invented (say tribar effect testing the new concept of psychological time described in [H1]! The crucial demonstration is however at the level of mere logic: 0 and 1 are the numbers needed, no experiments testing 10:th decimal for some quantitative prediction are needed.

Dissipation can be seen also as direct signature for consciousness and existence of selves Any system, which has ability to dissipate, to grow older, must have moments of consciousness in some length scales. Living systems are not the only systems growing old. Buildings and cars and computers grow old. Hydrodynamic flow without external energy feeded gets older by gradually losing its velocity- (and Z^0 magnetic-) vortices. The rate of the energy loss by dissipation could be even seen as a rough measure for the level of consciousness.

The crucial question is however in which length scales quantum jumps occur: does all the dissipation occur in atomic length scales as standard physics strongly suggests or are all length scales involved as quantum criticality of TGD and new TGD based space-time concept suggest. Hydrodynamic flow is especially interesting example in this respect. The TGD based model for turbulent flow [D7]. with external energy feed assumes that dissipation occurs in all length scales: the decay of vortices of given radius to smaller vortices should therefore involve primitive consciousness in the length scale of the vortices. In turbulent flow with external energy feed there is stationary energy flow between space-time sheets of various sizes and this means that the level of consciousness, if indeed measured by energy dissipation, is same at various p-adic length scales involved. The crucial role of the classical Z^0 field and low energy neutrinos in TGD based description of condensed matter and biosystems suggest that neutrinos and Z^0 fields might provide hydrodynamical flows with rudimentary cognitive consciousness. In this picture life as we know it, is a result of continual quantum self-organization of the sea water: indeed, we are 70 per cent of sea water.

2.4 Co-operativity, long range correlations, zero modes and quantum entanglement

The generation of the long range order is one of the basic characteristics of the self-organized systems (the formation of Benard cells in Benard convection, the formation of Taylor's vortex belts in the rotation of a cylinder containing fluid, concentration patterns in Belounow-Zabotinsky reaction). In Benard convection the long range order corresponds to the formation of the Benard cells, whose size and shape depend on the temperature difference and the size and the shape of the vessel. In TGD Universe long range order can be generated in two manners.

The generation of long range order seems to be in contradiction with the fact that the increase of the energy feed should destroy macroscopic quantum bound states. For instance, in the case of Benard convection one could ask why one should not regard the stationary initial state as the state with maximal long range order. A possible way out of the dilemma is the fractal structure of the spin glass energy landscape. The external energy feed drives the system from the bottom

of the energy valley which corresponds to a product of uncorrelated valleys, and it sooner or later ends down to the bottom of a deeper energy valley corresponding to a more stable state for which there are long range correlations between the degrees of freedom associated with the values of the initial valleys.

Quantum entanglement between two selves destroys them as separate selves and creates higher level self, which behaves like single system. At the level of conscious experience this means formation of a 'whole' form its parts. An interesting question relates to the importance of quantum entanglement in self-organization and how closely it corresponds to the formation of long range correlations. 'Ontogeny recapitulates phylogeny' metaphor suggests that quantum entanglement is geometrically realized as the formation of join along boundaries contact and this would suggest that generation of quantum entanglement requires direct contact interaction. This does not however exclude the possibility of quantum entanglement in biosystems: the quantum entanglement between cells could be generated during the replication of cell. For instance, in Benard convection heating could lead to decay of fluid particles and create quantum entanglement between the degrees of freedom associated with distant fluid particles. Also the formation of join along boundaries contact condensates of large size (recall quantum criticality) could be involved in the formation of hydrodynamical quantum entanglement. Note also that quantum entanglement could occur between mindlike space-time sheets expected to be present even in hydrodynamical systems.

Zero modes are fundamental order parameters and genuinely TGD element and bound to predict interesting new physics. Zero modes characterize the size, shape, classical Kähler field of space-time surface, and are purely classical variables in the sense that a complete localization occurs in them in each quantum jump. Zero modes give rise to long range correlations in purely classical sense. This means that even macroscopic 3-surfaces can behave like elementary particles in zero modes: tornado is a good example of a locally chaotic particle like object. When two systems form a quantum bound state the corresponding space-time sheets are connected by join along boundaries bonds. This implies that half of the zero modes become quantum fluctuating macroscopic degrees of freedom and macrotemporal quantum coherence results. The generation of quantum bound states could be important even in phenomena like hydrodynamical self-organization.

Neural plasticity can be regarded as a self-organization. Sperry observed that when one splits the optical nerve of a frog, the nerve ends fuse again and frog begins to see [19]. It seemed obvious that nerve ends recombine randomly and genuine self-organization was in question. This hypothesis can be tested by rotating the eye of the frog by 180 degrees and looking what happens. If frog begins to see normally, genuine neural plasticity and self-organization is in question. If the field of vision is reverted then self-organization is not in question and nerve ends must somehow recognize each other, perhaps chemically. It was found that the frog begins to see things upside-down! A bad blow for self-organization paradigm at that time! Later it was however found that neural plasticity is a real phenomenon.

An interesting possibility (having at least entertainment value) to explain the disappointing result about frog's eye without losing the faith to self-organization in this particular case. Quantum entanglement might correlate the ends of the split nerve to form single coherent unit and to find each other after splitting. Biotelepathy would be in question! If this were the case, the paradoxical results of these experiments could be regarded as a direct support for biosystems as macroscopic quantum systems! In the same spirit one could also consider the possibility that the fundamental reason for why replication (and also pairing) occurs in biosystems is that replication and pairing creates quantum entangled systems just like the annihilation of photon creates quantum entangled pair of charged particles. In fact, it has turned out that the most elegant model for brain functioning results when one assumes that primary sensory qualia are experienced at a sub-cortical level, presumably at the level of the sensory organs. Quantum entanglement between brain and sensory organs and the TGD based view about long term memory allow to circumvent various objections against this view.

2.5 Self organization requires external energy feed

Essential for the self-organization is external energy feed (Benard convection and even the general intuition about biosystems as systems living in the boundary between chaos and order). This can be understood on basis of Negentropy Maximization Principle [H2]. Only bound state entanglement is stable against the self measurement cascade giving rise to a state preparation during quantum jump. When the system is subject to energy feed the bound states formed by the fused subselves decay and thus the number of selves increases and the system become more complex. Each self defines a self-organization pattern. At the level of very large energy feed system becomes chaotic.

The same principle applies in the case of brain and the level of metabolism determines whether brain is in a deep meditative state empty of mental images or in a chaotic state of high arousal. In [H3] a model of cognition based on the generation of hierarchical self cascades is proposed. Metabolism gives rise to the energy feed generating subselves. During meditation the energy feed is minimal and sub-selves bound state entangle to for very few sub-selves and a state of "one-ness" results. The fusion gives rise to a stereo consciousness (analogous to stereo vision resulting when left and right visual fields fuse).

2.6 Many-sheeted space-time concept and self-organization

TGD replaces ordinary space-time concept with a hierarchical structure of space-time sheets. For instance, in a proper TGD based description of Benard convection, there is hydrodynamics at each space-time sheet. The sheets of 3-space, which can be regarded basic units of flow (say vortices) at a given p-adic length scale appear as particles on larger space-time sheets. Space-time sheets form in a natural manner master-slave hierarchy: we must in general adopt our behavior to the slow dynamics of external world.

There are two kinds of space-time sheets: material space-time sheets and mindlike space-time sheets so that one can say that Matter Mind duality is realized in geometrical sense: of course, Mind is understood in the sense of cognitive representations only. Cognitive space-time sheets defined as almost vacuum space-time sheets having finite time duration provide a geometric model of self and one can understand psychological time and its arrow in terms of this concept. Psychological time can be identified as a zero mode characterizing temporal center of mass coordinate for mindlike space-time sheet having finite temporal duration. The arrow of psychological time follows from the drift of mindlike space-time sheet in the direction of future: the drift is caused by the fact that there is more room in the future of a given point of future lightcone than in its past. The simplest argument suggests that single quantum jump corresponds to an average increment of psychological time, which is of order CP_2 time about 10^4 Planck times. Mindlike space-time sheets form actually a hierarchy: there are cognitive space-time space-time sheets condensed on cognitive space-time sheets condensed on...

Space-time sheets can perceive external world with the help of the wormhole Bose-Einstein condensate on their boundaries. NMP tells that the subsystem with maximum quantum entanglement can perform quantum jump and in this quantum jump previous flow is replaced with a new one. The claim is that without these quantum jumps, hydrodynamics equations could *never* give rise to the self-organized patter of the Benard flow. Rather, the spatial structure of the convective flow would be random.

TGD suggests a model of nerve pulse and EEG based on Josephson junction formed by the wormhole BE condensates in cell interior and exterior. More generally, the hierarchical structures formed by weakly coupled super conductors of various types seem to provide a very elegant general realization of conscious quantum control. Josephson junction networks are known to be self-organizing systems. The coherent light created by linear bio-structures, such as microtubules and possibly also DNA, is also a school example of self-organization [20]. A gradual generation of phase coherence could in this case make possible the coherent oscillations of entanglement making

possible self-organizing quantum jumps.

2.7 Infinite primes and self-organization

p-Adic length scale hypothesis stating that the typical size of 3-surface is of order $L_p \simeq l\sqrt{p}$, l about CP_2 size, suggests that the p-adic prime associated with the 3-surface representing entire infinite universe is infinite. The construction of infinite primes [O2] suggests that the decomposition of infinite primes to finite primes corresponds to the decomposition of space-time surface to p-adic regions. This would mean that the effective p-adic topology in sector D_p of configuration space corresponds to infinite prime p coding in very well defined sense the decomposition of $X^4(Y^3)$ to p-adic regions and also providing effective topology of $X^4(Y^3)$ in asymptotic regions of it: this would explain the success of physics based on real numbers. There are reasons to believe that p-adic topology for infinite primes is effectively real topology for all practical purposes but that the formulation of quantum TGD in terms of infinite p-adic primes is very elegant since perturbation theory in powers of infinite prime p contains only two orders unless one is interested in infinitesimals.

In fact, there is entire hierarchy of infinite primes and infinite prime in general decomposes to infinite primes belonging to the lower level of infinity and at the bottom of this decompositional hierarchy are finite primes.

1. Infinite primes form a hierarchy such that infinite primes p_N at level N decompose in a well defined manner to infinite primes p_{N-1} at level $N-1$, which in turn.... decompose into infinite primes at the lowest level, which in turn decompose into finite primes.

2. The infinite primes of level $N-1$ label single boson and single fermion states of a supersymmetric theory. Therefore each infinite prime at level N corresponds formally to a many-particle state consisting of bosons and fermions. Those primes of level $N-1$ for which fermionic or bosonic occupation number are non-vanishing, define the entire system. 'Ontology recapitulates phylogeny' metaphor suggests that the occupied infinite primes correspond to space-time regions appearing in the decomposition of the space-time surface to regions with different effective p-adic topologies. Thus the effective topology of D_p and the spectrum of p-adic topologies for the space-time surfaces in D_p correspond to each other in one-to-one manner.

3. The occupied fermion states of level $N-1$ are analogous to a subsystem of the manyparticle state formed by fermions and bosons. By b), this subsystem corresponds to a union of p-adic regions of the entire space-time surface. A very tempting identification of this region is as the sub-universe to which NMP applies in the quantum jump. The sub-system of this sub-universe winning negentropy gain maximization race makes the quantum jump.

4. The conservation of fermion number is analogous to the conservation of energy implying that material space-time sheets have infinite time duration. This suggests that p-adic primes for which fermion number is non-vanishing correspond to material space-time sheets whereas bosonic occupation number correspond to the numbers of mindlike space-time sheets. This identification would give a complete correspondence between infinite primes of simplest kind and space-time sheets. One can however also more complicated infinite primes.

5. Actually space-time sheets identified in this manner form an entire hierarchy since similar decomposition occurs for each infinite prime at level $N-1$. The lowest level corresponds to infinite primes having decomposition to finite primes.

p-Adic evolution means that the infinite prime associated with space-time surfaces appearing in final states of quantum jump increases in the long run. The increase of the p-adic primes associated

with finite space-time regions in the long run and implies also the increase of infinite prime. This means that evolution at global level is implied by local evolution.

2.8 Illness as a failure to self-organize properly

One can consider two definitions of illness.

1. Structural illness: Illness as a loss of quantum coherence at some level. For instance, some group of neurons fails to form a quantum coherent system.

2. Functional illness: Illness as the failure to self organize effectively. For instance, cancer cells fail to organize to larger coherent units and behave in a selfish manner. Here Negentropy Maximization Principle suggests a manner to understand illness.

Actually, 1) might reduce to 2) since biosystems are not static systems but more like vortices in a stream with fluid particles being replaced with new ones all the time: self-organization creates various subsystems again and again. It seems indeed possible to understand the illness qualitatively in TGD based theory of self-organization.

In TGD framework one can envision living system as a dynamical hierarchy of selves. For instance, cognitive acts corresponds to self cascades, our thoughts correspond to subselves as also do various components of sensory experience. In this picture illness is pathology resulting from the inability of some subselves to wake-up properly or at all. If some such subsystem fails to wake-up, this subsystem is unconscious and thus system could be said to be ill. Subsystem can wake-up either by quantum jump or spontaneously when the entanglement entropy of subsystem falls below the critical value determined by the pinary cutoff. Thus one can say that healthy biosystem consists of maximally alert subsystems able to wake-up either spontaneously or by quantum jump. Getting tired means that the real entanglement of self with external world become nearly critical and system becomes drowsy. The need of the subsystems waking gup by quantum jump to regenerate entanglement could be one reason for why we must sleep. Biosystem can also 'eat' entanglement or ability to generate it: one purpose of the metabolism would be to feed entanglement to make possible quantum jumps leading to dissipation and self-organization.

From above one can conclude that illness as a failure to self-organize in normal manner is basically a failure to generate generate normal patterns of self-hierarchy. Some part of biosystem does not receive the needed entanglement entropy feed. 'Metabolism does not work properly' would be a more familiar manner to state the same thing. The mysterious ability (from classical physics point of view) of a self-organizing system to repair itself (get cured) can be understood as a consequence of the fact that system ends up with some self-organization pattern (fixed point of iteration) automatically.

Some examples are useful to clarify these ideas.

1. Healthy heart is sufficiently chaotic, not ordered. Interpretation: there must be a feed of entanglement and hence of entropy to make heart able to rapidly self-organize.

2. According to TGD based model of nerve pulse and EEG [M2, M3], EEG is directly related to the oscillations of Bose-Einstein condensate associated with the neurons and possibly also glial cells. EEG could well be accompanied by oscillations in quantum entanglement. Large group of neurons would have simultaneously minimum or maximum entanglement with the surrounding world and they could wake-up spontaneously or by quantum jump: firing could be related to this wake-up. If the coherence of EEG is lost, neuron group ceases to behave like a coherent unit firing synchronically. The spatial coherence of EEG in brain could be a measure for quantum coherence of brain. The spatial coherence EEG is indeed known to reflect psychic disorders. Similar loss of coherence could explain the behavior of cancer

cell population and an interesting possibility is that some EEG type collective oscillation is missing from cancel cell population.

3. The feed of thermal energy means the feed of entanglement entropy and the lowering of the temperature leads to the lowering and even loss of consciousness. The development of organisms which could control their temperature and thus stay conscious all the time was one the great evolutionary steps. The same argument could explain also the tendency to get ill as a consequence of getting cold. The raise of the body temperature during illness could be regarded as an attempt of the body to produce surplus quantum entanglement to make possible the self-organization process leading to curing. Hallucinations associated with the fever could perhaps be regarded as a pathological state in which the enhanced entropy production leads to a pathologically high level of consciousness involving virtual perceptions.

3 Haken's theory of self organization

Haken's classical theory of self-organization and the related model of pattern recognition (see the book "Information and Self-Organization" [20]) is rather attractive in its simplicity and generality. Of course, the model cannot tell how the conscious experience associated with the pattern recognition is created but the concept of quantum jump might provide this lacking piece. The model generalizes also to a description of how biosystem acts on external world.

The potential wells representing attractors of the classical dynamics of the order parameter are replaced by the maxima of the Kähler function with respect to non-zero modes in quantum TGD based model. The zero modes of the configuration space geometry serve as control parameters and maximum depends on them. There are several maxima for given values of zero modes so that a typical catastrophe theoretic situation results and non-equilibrium phase transitions become possible.

3.1 Haken's theory of non-equilibrium phase transitions

The basic elements of Haken's theory [20] are the concepts of order parameter and Slaving Hierarchy, Langevin and Focker Planck equations, maximum entropy principle and non-equilibrium phase transitions associated with the fluctuations of the order parameter at criticality.

a) Dynamical variables

Order parameters, denote them by q, are the fundamental dynamical variables in Haken's theory. They could be chemical concentrations, densities, some parameter specifying the geometrical conformation of system, etc. The basic element in Haken's theory is master-slave hierarchy. Slave possesses swift dynamics which follows the much slower dynamics of the master. Master typically appears as an external slowly varying parameter in the dynamics of the slave. In TGD larger space-time sheet, external world, typically serves as a master of the smaller space-time sheet, perceiver, in sensory perception. Situation could be also reversed: the reaction to the sensory experience is good example of this! p-Adic length scale hierarchy is a good example of master-slave hierarchy.

b) Dynamics

The dynamics of the order parameter is determined by a dissipative force proportional to the time derivative dq/dt of the order parameter, conservative force field defined as a gradient of a potential function $V(q)$ and random fluctuating force $F(t)$. In equilibrium the velocity is determined from the requirement that acceleration vanishes and this condition is known as Langevin equation. Potential function contains as external parameters the slowly varying order parameter of the master.

Fokker-Planck equation describes the devopment for the probability distribution $f(q,t)$ associated with the order parameter (an ensemble of identical systems is assumed: for instance, cells could form this kind of ensemble). Fokker-Planck equation is just the continuity equation for the probability density and the associated probability current containing convective term $\nabla_q V f$ proportional to the gradient of the potential $V(q)$ and a diffusive term proportional to the gradient $\nabla_q f(q,t)$ of the probability density.

c) Equilibria and maximum entropy principle

In non-equilibrium thermodynamics the requirement that entropy is maximal implies that in equilibrium situation the probability density $f(q)$ is proportional to the exponential of the potential function $V(q)$ and is hence analogous to Boltzmann weight:

$$f_{eq}(q) = N exp(-\frac{V(q)}{K}) \ .$$

K is analogous to temperature. V determines single particle correlation functions $\langle q_i \rangle$, two-particle correlation functions $\langle q_i q_j \rangle$ and also higher correlation functions for the components of the order parameter and this gives means of deducing the function V from experimental data. Typically a Gaussian modified with a fourth-order interaction terms is in question. There is a direct analogy with Higgs potential and non-equilibrium phase transitions have interpretation as symmetry breaking/restoration.

d) Non-equilibrium phase transitions

Non-equilibrium phase transitions are induced by a change in some parameter of the potential, typically the coefficient b of the quadratic term in

$$V = bq^2 - aq^4 \ ,$$

which represents master type order parameter itself. For instance, single potential well ($b < 0$) becomes unstable when b becomes positive ($b > 0$) and order parameter moves to either well of the double well potential. In a deformed potential Langevin equation leads rapidly to a new attractor corresponding to the free energy minimum of the potential: order parameter is captured by the nearest attractor. In Focker Planck equation spontaneous symmetry breaking with a selection of second potential well occurs.

3.2 Pattern recognition in Haken's theory

1. Perception gives rise to order parameter describing information about the external world. Visual field of the eye is a good example.

2. Each attractor of the order parameter dynamics corresponds to a characteristic pattern, feature. Grandma, apple, etc..

3. Pattern recognition is essentially feature detection and completion of the pattern to one of the characteristic patterns. Features are preferred patterns of q, which correspond to the minima of the free energy associated with the order parameter in question. Formally, features correspond to the eigenvectors of the quadratic part of the free energy determined by the inverse of the quadratic form defined by the correlation functions of the components of the order parameter.

4. Perception creates a pattern of the order parameter q. If the system is above criticality (there is minimum feed of metabolic energy to guarantee that one has $b > 0$ in the potential function) this leads to a rapid dynamics (Langevin equation) leading from the pattern near an attractor to the attractor, the feature. The dynamics clearly creates caricatures.

4 Non-equilibrium thermodynamics and quantum TGD

Quantum TGD suggests the replacement of Haken's theory with a quantum description based on the generalization of the Thom's catastrophe theory to configuration space context and the introduction of spin glass analogy and p-adic fractality at the fundamental level. The facts that localization in zero modes and to the sector D_p of configuration space occurs in each quantum jump, imply that TGD based theory is in many respects very much like Haken's theory. The concept of quantum average effective space-time defined as maximum of Kähler function for given values of zero modes, allows even more classical description.

4.1 Spin glass analogy

At the level of the configuration space geometry spin glass analogy is well understood. The configuration space CH consisting of 3-surfaces in H has fiber space structure. Fiber corresponds to nonzero modes of configuration space metric contributing to the line element of metric and base corresponds to zero modes in which line element vanishes. Spin-glass analogy implies large degeneracy of the absolute minima of Kähler action. In the approximation that classical gravitation can be neglected all extremals of Kähler action are degenerate and CP_2 canonical transformations are $U(1)$ gauge symmetries in fiber degrees of freedom: actually however $U(1)$ gauge symmetry is broken and the gauge-related space-time surfaces are not gauge-equivalent configurations so that spin-glass analogy results. The functional integration around maxima of Kähler function as function of fiber coordinates gives well define results since Gaussian determinant and metric determinant cancel each other.

The assumption that localization in zero modes occurs implies that there is no need to integrate over zero modes in the calculation of transition rates: integration is however needed in the treatment of the generalized unitarity conditions for p-adic valued S-matrix elements. Zero modes characterize the shape and size of the 3-surface as well as its classical Kähler electric and magnetic fields. These zero modes are an essential element of the spin glass degeneracy. The natural interpretation of zero modes is as order parameters.

Besides zero mode degeneracy there is the degeneracy associated with the absolute minima of the Kähler action for given values of zero modes characterizing 3-surface Y^3. A natural hypothesis is that this degeneracy is at least partially characterized by the decomposition of the space-time surface $X^4(Y^3)$ to space-time sheets labelled by p-adic primes. Mindlike space-time sheets (association sequences) having finite time duration are an essential aspect of this degeneracy and one could roughly say that the presence of thoughts represented geometrically by mindlike space-time sheets is what gives rise to the (cognitive) degeneracy. Of course, also material space-time sheets can behave nondeterministically and it is this kind of degeneracy which gives rise to volitional acts with macroscopic consequences.

An attractive possibility is that localization in zero modes and localization in D_p imply that final state space-time surfaces are macroscopically equivalent and that integration over fiber degrees of freedom reduces to integration around single maximum of Kähler function. It might be that reduction to integral around single maximum of Kähler function is actually implied by mathematical consistency. This would mean huge simplification in the construction of the theory since very close resemblance with the formalism of quantum field theory would results as a consequence. The physical picture of quantum field theories certainly suggests this strongly. In particular, the localization in zero modes and the selection of single maximum of Kähler function in fiber degrees of freedom is the TGD counterpart of Higgs mechanism.

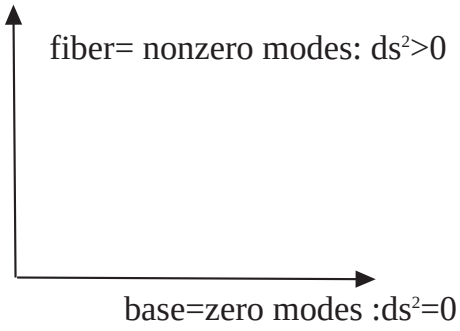

Figure 1: Configuration space has fiber space structure. Fiber corresponds to coordinates appearing in the line element and base to zero modes, which do not appear in the line element.

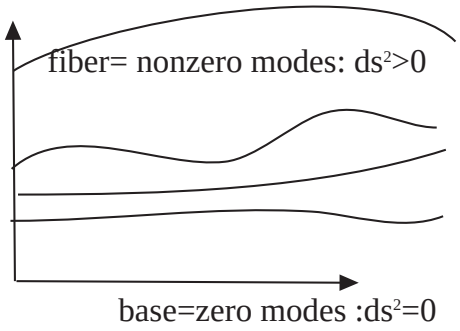

Figure 2: The reduced configuration space CH(red) has many-sheeted structure with each sheet parameterized by zero modes.

4.2 Maxima of the Kähler function as reduced configuration space CH_{red}

When one calculates the probability amplitude for a given quantum jump, given as the inner product between configuration space spinor fields, one obtains an integral of the fermionic Fock space inner product as a functional of 3-surface X^3 over fiber degrees of freedom around maxima of Kähler function as function of fiber coordinates: if the most optimistic expectations are realized, only single maximum contributes. This integral can be calculated approximately by performing Gaussian perturbation theory. Thus the *maxima* of the Kähler function, which are completely analogous to the free energy minima of spin glass, can be identified as the reduced configuration space CH_{red}. The ill defined Gaussian and metric determinants cancel each other and the non-locality of Kähler function as a functional of 3-surfaces implies that the standard divergences of the local quantum field theory are absent.

The number of maxima for given values of zero modes can be large: this is in fact expected since only classical gravitational action differentiates between canonical transforms of a given absolute minimum space-time surfaces. In particular, the presence of mindlike space-time sheets is expected to give rise to huge degeneracy. Thus CH_{red} has many-sheeted structure which each sheet parameterized by zero modes and a generalization of catastrophe theory to infinite-dimensional

context is needed to describe the situation mathematically. This degeneracy corresponds in the simplest case to the degeneracy of state associated with cusp catastrophe and phase transition like quantum jumps corresponds to selection of one of the various allowed branches.

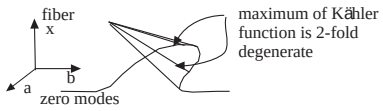

Figure 3: Cusp catastrophe. In this case CH_{red} has two sheets (intermediate sheet is not maximum of Kähler function).

The simplest manner to understand the expected decomposition of the reduced configuration space to different regions D_p characterized by various p-adic primes is to assume that $exp[K_{max}]$ is p-adic fractal as a function of the zero modes. p-Adic fractality is suggested by criticality and spin glass analogy. p-Adic fractality implies automatically ultrametric hierarchy at the level of configuration space allowing the decomposition of CH_{red} to a tree like structure. This kind of hierarchy is suggested by Parisi [18] to be fundamental for the biological information processing, especially for the formation of concepts and classification into categories.

4.3 The concept of quantum average effective space-time

If the most optimistic expectations hold true, functional integration in fiber degrees of freedom reduces to integration around some maximum X^3_{max} of Kähler function with respect to fiber coordinates. It is convenient to identify the space-time surface $X^4(X^3_{max})$ as 'quantum average effective space-time'. Since configuration space integration occurs over the sector D_p associated with the final state of the quantum jump, effective quantum average space-time characterizes final state and can be regarded as a representative example from the set of space-time surfaces appearing in the final state, which all have same macroscopic characteristics.

One can associate this space-time surface only with the final state of the quantum jump and the sequence of quantum jumps defines a sequence of space-time surfaces of this type. As already explained, dissipative time evolution can be interpreted as kind of envelope for this sequence of reversible time evolutions. Classical Langevin dynamics for order parameters can be identified as the counterpart of the hopping in zero modes and in degrees of freedom characterizing various degenerate absolute minima associated with the maxima X^3_{max} of Kähler function.

4.4 Haken, Thom, Penrose and Hameroff

The picture leads to a generalization of Haken's theory of non-equilibrium phase transitions to a Penrose-Hameroff type picture [22]. Any quantum jump corresponds to a selection of space-time surfaces as the relevant maximum of Kähler function and the fundamental order parameters are the zero modes characterziing the space of these 3-surfaces. Non-equilibrium phase transitions correspond to quantum jumps leading to a selection of one maximum, from a quantum superposition of several ones appearing in the state $U\Psi_i$. The classical theories of Haken and Thom correspond to the hopping motion in zero modes. The sequence of quantum jumps leads to the regions of configuration space at which vacuum functional is maximum and when Kähler function has several maxima this leads with great probability to hopping from one sheet of the catastrophe surface to another. For volitional quantum jumps selecting between maxima of Kähler function in fiber degrees of freedom, one ends up with the quantum versions of these theories in which genuine

phase-transition like quantum jump selecting between the sheets of the catastrophe surfaces occurs near the 'Maxwell line': the Penrose-Hameroff proposal [22] for the orchestrated reduction of state function is analogous to this kind of selections.

4.5 Classical gravitation and quantum jumps

For given values of zero mode parameters several maxima are possible. The reason is that the canonical transformations of CP_2 acting as local $U(1)$ gauge transformations leave zero modes invariant and generate new absolute minimum space-time surfaces. Only the classical gravitational interaction energy breaks local $U(1)$ invariance as a gauge symmetry of the Kähler action and differentiates between these surfaces. The value of the Kähler function depends only very weakly on these degrees of freedom. Very many nearly degenerate maxima are expected and these degenerate maxima are the TGD generalization for the gravitationally degenerate microtubule conformations of Penrose and Hameroff [22]. In Penrose-Hameroff theory gravitons are expected to play important role. In fact, the vacuum Einstein tensor associated with the absolute minima generates coherent state of gravitons. An interesting possibility is that this coherent state of gravitons gives rise to the sense of proprioception.

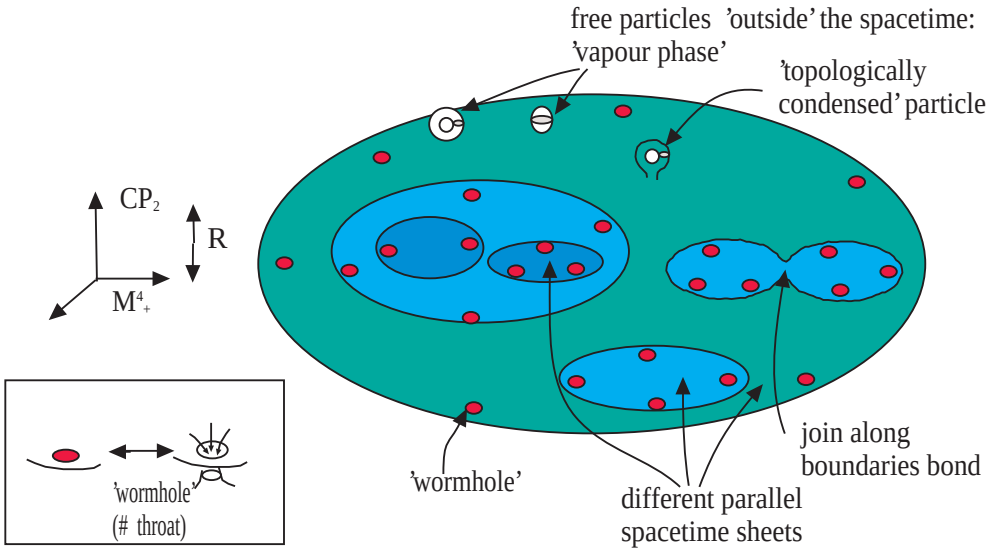

Figure 4: Topological condensate and vapor phase: two-dimensional visualization.

4.6 A quantum model for perception and reaction

All quantum jumps involve both active and passive aspects and it is interesting to look for a general model for active (reaction) and passive aspects (perception) of consciousness based on the generalization of Haken's theory.

In TGD fundamental order parameters correspond to zero modes of configuration space. In TGD framework the dynamics for order parameters corresponds basically to hopping in the space of order parameters: the time increment for single hop is about 10^4 Planck times if the simplest estimate holds true. Therefore the statistical description of hopping as a continuous motion is

expected to be an excellent approximation. The motion is much like Brownian motion in presence of drift term. Langevin dynamics for order parameters can be regarded as a model for the hopping in the space of order parameters. Focker-Planck dynamics applies, when the number of nearly identical space-time sheets each characterized by zero modes is large so that one can apply quantum statistical determinism. One can also introduce probability distribution also for single space time sheets to describe the distribution of zero modes defined by quantum jumps during some macroscopic time scale (roughly 10^{40} quantum jumps occur during second inside self if the simplest estimate holds true!)

The hopping in the space of order parameters must lead to the region of order parameter space in which configuration space spinor field has maximum. The simplest situation is that the maxima correspond to the maxima of vacuum functional as function of order parameters. Since vacuum functional is exponential of Kähler function, this means that Kähler action for space-time sheet representing subsystem containing zero modes as external parameters takes the role of the potential function in Haken's theory.

If sensory experience is determined by the localization in zero modes then feature detection must correspond to Langevin type dynamics leading to some minimum of potential function and in TGD it corresponds to a hopping motion leading to attractors defined by several maxima of the Kähler function as a function of zero modes. For instance, in case of cusp catastrophe quantum jumps lead rapidly from the stable sheet of catastrophe to another in the vicinity of Maxwell line. Conscious feature detection would require that there is self whose sensory experience is dictated by the localization in zero modes characterizing feature. It seems that this requires macroscopic quantum phases whose order parameters in ground state are determined by the values of zero modes. The essentially quantal element of the feature detection is the wake-up of the subself whose subsequent self-organization gives rise to a mental image depending only weakly on initial conditions. A general model for this wake-up mechanism is based on the quantum jumps induced by Josephson currents running between two superconductors representing master and slave. These quantum jumps are induced resonantly in slaved superconductor, when the frequency of the Josephson current corresponds to the energy difference for the states of the slaved superconductor [I4, I5].

Besides hopping motion there are volitional acts identifiable as selections between the degenerate absolute minima of Kähler action. Physically it seems obvious that volitional acts select between initial value sensitive dynamical developments of 3-surface. The selections between degenerate absolute minima do not correspond to localization in zero modes characterizing single 3-surface but to the fixing of the presumably infinite p-adic prime characterizing entire surface $X^4(X^3)$. This selection means partial localization in the fiber of the configuration space rather than in base (zero modes). This quantum jump represents genuine quantum catastrophe and it is not at all clear whether it is modellable Langevin dynamics. One could approximate this dynamics by hopping motion by introducing the concept quantum average space-time obtained by replacing the fiber with the space of the space-time surfaces, which correspond to the maxima of of Kähler function with respect to fiber coordinates (rather than zero modes as in previous case). The statistical average dynamics could be described as hopping motion in the reduces space of maxima.

The recognition of phonemes takes place in definite places in the linguistic regions of brain. This suggests that the same input comes into each of these detectors and gives rise to yes-no response so that cusp catastrophe is in question. The assumption that various phoneme detectors receive same input data is in accordance with the ideas about hologram like data representation in brain. Generalizing, it seems that some parts brain could be to some extend act as a collection of simple yes-no feature detectors receiving essentially the same input.

4.7 Are proteins quantum spin glass type systems?

The entire universe should be quantum spin glass type system if TGD is correct. There is indeed some evidence for the spin glass nature of biosystems at protein level [17]. A long standing problem of molecular biology is to understand why proteins fold to very few preferred spatial conformations only. A naive expectation, assuming *random* amino-acid sequences, is that folding should occur randomly.

According to the article [17], Ken Dill has simulated proteins using a simplified computer model in which the 20 amino-acids are replaced with 2 model aminoacids: 'hydrophobic' or 'hydrophilic'. It has turned out that only few per cent of these virtual proteins are good folders. The lesson seems to be that random sequences of aminoacids are not sufficiently protein like and that good folders have some specific property allowing them to arrive at a unique shape.

According to the same article, Peter Wolynes suggests that proteins are spin glass type systems characterized by a fractal like energy landscape containing very many nearly degenerate energy minima. This means that system has difficult time in finding low energy arrangements and it can end up to any one of the very many energy minima with almost degenerate energies. Therefore *typical* spin glass like system is not a good folder. Wolynes suggest that, as a consequence of natural selection, real proteins differ from random proteins in that they have one deep energy minimum besides shallow minima still present. The energy landscape is still rugged but now there is one preferred configuration at the bottom of a deep energy valley. Also the states near this state are assumed to have energy below the average energy. This funnel like structure in energy landscape is proposed to be a solution to the folding paradox. One can understand the correct folding to result from external perturbations: if protein is put in hot liquid, thermal perturbations take care that it is not left in any local energy valley during cooling but ends up to the deep energy minimum. Minimization of free energy could also selet good folders during evolution starting from a soup of random aminoacid sequences.

If protein is in self state, quantum jumps inside it occur and imply quantum self-organization leading to preferred final state pattern selected by dissipation. This pattern represents protein folding depending on the external parameters like pH, ionic concentrations and temperatures whereas the dependence on the initial state is very weak. Thus the phenomenon of protein folding gives direct support for the self-hierarchy and consciousness in even protein length scales. p-Adic length scale hypothesis suggests that the duration of the protein self is of order $T_p = L_p/c$, which for the p-adic length scale $L(151) \simeq 10^{-8}$ meters gives $T_p \sim 10^{-15}$ seconds: during this time protein self can perform huge number of (something like 10^{26}) quantum jumps so that self-organization certainly occurs.

Wolynes models protein as a thermal spin glass. TGD suggests that the entire universe is quantum spin glass. The partition function of spin glass (or rather the average over the partition functions with different coupling strengths between spins) is replaced with vacuum functional, which is exponent of the so called Kähler function. The averaging over the coupling constant strengths corresponds in TGD to the average over so called 'zero modes' of the Kähler function: using QFT terms, these degrees of freedom do not couple to the inverse of the propagator defined by the Kähler function. Zero modes characterize the shape and size of the 3-surface and also the classical induced Kähler field on it (classical em field is very closely related to Kähler field) and can be identified as fundamental order parameters in TGD inspired quantum theory of self-organization. In each quantum jump localization in zero modes occurs so that averaging is indeed genuine statistical averaging: quantum states representing the final states of quantum jumps are not delocalized in zero modes. Evolution at quantum level has selected those proteins for which the rugged 'energy landscape' defined by the negative of Kähler function contains only few deep minima. One can criticize the assumption about the selection of the spin glass energy landscape as too strong. There are always deep minima and depending on the initial conditions self-organization leads to some minimum. On the other hand, selection certainly occurs also in the sense that proteins

and corresponding spin glass energy landscapes are selected by evolution.

The proposed mechanism might be a general mechanism of evolution. In the generalization of Haken's self-organization theory to quantum TGD context the maxima of the Kähler function correspond to those configurations to which self-organizing system rapidly moves if perturbed. For instance, pattern perception could be described as a dynamical evolution leading to one of few maxima identifiable as 'features', which are caricature like patterns providing idealization of the actual sensory stimulus. 'Features' would correspond to configurations with one deep minimum of the negative of the Kähler function selected during evolution. Also preferred behavioral modes developed during evolution, 'phylogenetic invariants', could have similar identification.

As a matter fact, quantum self-organization should occur even in elementary particle length scales. The duration of elementary particle selves can be estimated from the p-adic length scale hypothesis to be of the order of Compton time determined by the particle mass. Self-organization could explain the selection of preferred p-adic primes characterizing elementary particles and also macroscopic space-time sheets.

4.8 Cognitive evolution as self-organization of association sequences

In the proposed picture cognitive evolution can be regarded as a self-organization of association sequences. Association sequences can develop not only the ordinary space-like quantum entanglement but also combine to form longer association sequences having quantum entanglement in time direction. The emergence of association sequences characterized by increasingly larger value of p-adic prime corresponds to the development of larger coherent cognitive units. The formation of association sequences of association sequences corresponds to the formation of cognitive slaving hierarchies. The replication of association sequences provides a geometric realization for the idea of ideas as living organisms. Mindlike space-time sheets are a particular example of association sequences and are geometric correlates for selves.

4.9 Brain as a self-organizing quantum spin glass

The plasticity of brain is consistent with the identification of brain as quantum spin glass. In this picture the evolution of subselves/mental images is a dissipative self-organization process leading to some asymptotic self-organization patterns which correspond to the valleys of the spin glass energy landscape of brain. One can understand development of memories, habits, skills and even fix idees as a quantum self-organization based on Darwinian selection of subselves having nerve pulse patterns and synaptic strengths as neural correlates.

The crucial element of the self-organization is external energy feed making possible interesting self-organization patterns. One role of the nerve pulses is to provide this metabolic energy feed. Nerve pulses affect the postsynaptic cell: typically excitation or inhibition is in question. The interpretation is again that the incoming nerve pulses push and pull the postsynaptic cell in different directions in spin glass energy landscape and in this manner cause frustrations typical for spin glass like systems. Also frequency and time codings and the lack of a precise neuronal code are consistent with this.

This picture is not in conflict with the idea that nerve pulse patterns determine conscious experience to a high degree. This is indeed the case if axons give rise to standard experiences determined by axon-specific macroscopic quantum phases such that only the intensity of the axonal contribution to the conscious experience is affected by the firing rate. In this picture brain becomes analogous to music instrument and nerve pulse patters take the role of the player of the instrument. Quantum spin glass paradigm combined with the notion of the geometric memory leads to a general model of long term memories circumventing the basic difficulty of the neural net models of long term memory related to the fact that long term memories identified as synaptic strengths tend to be destroyed by the learning of new memories.

5 Could TGD provide justification for the ideas of Rupert Sheldrake?

Rupert Sheldrake [21] has developed a theory of learning and memory based on the concepts of morphic fields and morphic resonance. The basic hypothesis is that learning occurs also at the level of species. If some individuals of the species have learned some habit then it becomes easier for the remaining individuals of the species to learn the same habit. The individuals who learned the habit first need not even live anymore or can live in a distant part of the world. Morphic fields are much like order parameters in Haken's theory and collective learning is claimed to occur in a morphic resonance analogous to a phase transition leading from a small seed of invididuals with new habit to a population having the same habit. Morphic fields however have also another aspect: morphic field provides a representation for habit and resemble the concept of meme in this respect. Sheldrake postulates also some kind of creativity besides morphic resonance serving as a selector of habits. It is interesting to find whether TGD could suggest any physical identification for the concepts of morphic field, morphic resonance and creativity.

5.1 Collective memory, geometric memory and self hierarchy

Sheldrake states the basic assumptions of his theory in the following manner:

The idea is that there is a kind of memory in nature. Each kind of thing has a collective memory. So, take a squirrel living in New York now. That squirrel is being influenced by all past squirrels. And how that influence moves across time, the collective squirrel-memory both for form and for instincts, is given by the process I call morphic resonance. It's a theory of collective memory throughout nature. What the memory is expressed through are the morphic fields, the fields within and around each organism. The memory processes are due to morphic resonance.

TGD predicts infinite hierarchy of selves and if this hierarchy has levels between living systems and entire universe, then the idea about collective memory makes sense and generalizes to entire hierachy of them. Higher level selves must give rise to effective morphic fields affecting the behavior of the lower level selves. The phenomenon of bio-feedback is direct evidence for this phenomenon in a length scale familiar to us. By monitoring the behavior of say single neuron, it is possible to learn to affect the behavior of neuron volitionally. No knowledge about how this happens: only the volition is needed. The natural guess is that volition affects the value of a morphic field affecting the behavior of neuron. The possibility of biofeedback suggests the possibility of socio-feedback and feedback even at the level of species and entire biosphere.

Geometric memory provides perhaps the only viable candidate for the mechanism of a long term memory. Geometric memory is made possible by the fact that self can have multitime experiences such that the mindlike space-time sheets associated with various values of the geometric time give contributions to the experiences and past contributions are experienced as memories. Since our geometric past and future change in each quantum jump these memories are not stable: long term memories are certainly unreliable. The memory formation mechanism of brain however tends to stabilize these memories. There is in principle no upper bound for the span of the geometric memories and one can consider the possibility of racial memory and even species memory. Under suitable conditions organism could be able to have the mindlike space-time sheets of the geometric past as its subselves and experiences these memories. Thus geometric memory is at least consistent with Sheldrake's claims and to some degree supports them.

5.2 Identifying morphic fields

There are no obvious candidates for the morphic fields in the framework of the standard physics. In TGD context situation is however different: one can in fact imagine two possible identifications.

The obvious identification of classical morphic fields is as zero modes whereas quantal morphic fields could can be identified as quantum fields describing mindlike space-time sheets. One could regard these realizations as classical and quantal counterparts of morphic fields completely analogous to classical and quantal electromagnetic fields in TGD framework. Even more, the hypothesis that zero modes determine all macroscopic quantum phases, in particular the quantum phases associated with mindlike space-time sheets, would mean that these two identifications are mutually consistent.

Topological field quantization allows to identify very precise geometric counterparts of various quantum notions. Virtual particles seem to correspond to mindlike space-time sheets. This suggests that morphic fields correspond to the classical counterparts for the quantum fields. Negative energy mindlike space-time sheets, which are also possible, would correspond to annihilation operators whereas positive energy space-time sheets would correspond to creation operators. Therefore the decomposition of a given space-time surface to material and mindlike space-time sheets could perhaps be regarded as analogous to single oscillator operator combination in the superposition of the quantum field in terms of creation and annihilation operators associated with the free fields. The localization to zero modes occurring in each quantum jump would mean a selection of single component of this kind in the state created by the quantum field.

5.2.1 Classical morphic fields as zero modes?

One can distinguish between classical and quantal morphic fields. The most obvious identification of the classical morphic fields is as classical fields identifiable as zero modes serving as master for the learner and affecting phase transition in the slave like zero modes of learner identifiable inducing learning. The members of the species correspond to space-time sheets, 3-surfaces, which can be regarded as particles in a generalized sense. The generalization of a point particle to 3-surface means the introduction of zero modes characterizing the size and and shape as well as the classical Kähler field (in many cases essentially electromagnetic field) associated with the space-time surface in question. These zero modes are not encountered in quantum field theories and mean new physics. Evolution means gradual hopping in the space of zero modes leading to average increase of the p-adic primes characterizing various space-time sheets.

TGD leads to a generalization of Haken's theory of self organization [20] to quantum context and zero modes can be identified as universal order parameters in the spirit of Haken's theory of self-organization. Morphic resonance could be identified as a quantum counterpart of a non-equilibrium phase transition involving large long range fluctuations in the slaved order parameters characterizing the state of the learner: learning would represent phase transition like phenomenon in which new minimum of free energy emerges and leads to change in the behavior. This transition would be induced by slowly varying order parameter representing morphic field and reaching critical value in transition. Morphic field could characterize large part of biosphere and its variation at criticality would induce phase transition representing learning, which could occur globally. The almost simultaneous learning of large number of members of species learn claimed by Sheldrake would *not* follow from the fact that some members have already learned but from the global variation of order parameter serving as master. Of course, one could also imagine that the variation of the global order parameter inducing the phase transition leading to learning might be conscious socio-feedback of Mother Gaia!

5.2.2 Morphic fields as cognitive quantum fields?

Sheldrake defines morphic fields in the following manner:

Basically, morphic fields are fields of habit, and they've been set up through habits of thought, through habits of activity, and through habits of speech. Most of our culture is habitual, I mean most of our personal life, and most of our cultural life is habitual. "We don't invent the English

language. We inherit the whole English language with all its habits, its turns of phrase, its usage of words, its structure, its grammar.

It seems that this characterization is not totally consistent with the identification of the classical morphic fields as zero modes. Change in zero modes could induce learning but the representation of habits themselves seems to require something more. The concept of meme as a counterpart of morphic field representing habit suggests itself.

Learning is related to cognition and in TGD cognitive space-time sheets provide a model for cognition. Mindlike space-time sheets are in many respects like particles except that they have vanishing total quantum numbers. Mindlike space-time sheets could be also closed space-time surfaces, which are global vacua and glued to the material space-time surfaces by topological sum contacts (tiny wormholes). Mindlike space-time sheets are like memes and meme as gene metaphor suggests itself. The replication of mindlike space-time sheets could be analogous to replication of DNA and cells and could be actually be the mechanism inducing these replications. Zero modes could basically control the replication and determine the distribution of mindlike space-time sheets.

One could however go further. These particle like features of mindlike space-time sheets suggest the possibility of describing mindlike space-time sheets using quantum fields, whose modes are labelled by discrete labels characterizing various sheets. One can consider the possibility that memes and quantal morphic fields correspond to the quantum fields describing mindlike space-time sheets. Sheldrake's assumption that morphic fields are everywhere would suggest that the quantum fields defining mindlike space-time sheets reside on all space-time sheets just like photons and gravitons do. Indeed, the fact that mindlike space-time sheets are vacuum fields and therefore do not carry four-momentum and mass suggests that the quanta of these fields can propagate over arbitrarily long distances.

There are objections against the idea of cognitive quantum field.

1. The hypothesis that center of mass spatial and temporal coordinates of mindlike space-time sheets correspond to zero modes means that localization of mindlike space-time sheets occurs in each quantum jump. Thus one cannot visualize mindlike space-time sheets as ordinary quantum particles moving in kind of planewaves and it would not be sensible to speak about delocalized cognitive space-time sheets. Of course, one might consider the possibility that the entanglement coefficients do not depend on zero modes characterizing the positions of mindlike space-time sheets: in this case it could be possible to have quantum jumps in which delocalization in zero modes does not occur.

2. It is also questionable whether one can apply harmonic oscillator model in the discrete degrees of freedom characterizing mindlike space-time sheets and making the concept of Bose-Einstein condensation idea more than a metaphor. Mindlike space-time sheets possess however fiber degrees of freedom and also fermionic degrees of freedom and it might be possible to identify harmonic oscillator degrees as these degrees of freedom. These states however correspond to states of single mindlike space-time sheet and one should understand how the correspondence with states consisting of many mindlike space-time sheets arises. This kind of problem is in fact encountered already in case of ordinary elementary particles. The correspondence between the topological description of many particle states in terms of CP_2 type extremals and in terms of Fock states is not completely understood: it however seems that CP_2 type extremals having quantum numbers of many particle states are unstable against decay to CP_2 type extremals representing single particle states. Similar situation might prevail in case of cognitive space-time sheets: mindlike space-time sheet which is excited in fiber degrees of freedom to a state described by various occupation numbers decays to mindlike space-time sheets such that only one of these occupation numbers is non-vanishing for a given mindlike space-time sheet.

Although the assignment of quantum fields to mindlike space-time sheets might be unrealistic, there seems to be a close connection with quantum fields, which connection could have even practical value allowing to estimate probabilities for the emergence of mindlike space-time sheets. The connection follows from topological field quantization implying rather precise correlation between quantum concepts and the structure of the space-time surface. Negative energy mindlike space-time sheets, which are also possible, would correspond to annihilation operators whereas positive energy space-time sheets would correspond to creation operators. One can assign to a component of quantum field corresponding to a given monomial of creation and annihilation operators a space-time surface representing this component and classical space-time surface is analogous to Bohr orbit by absolute minimization of Kähler action such that mindlike space-time sheets of finite time duration represent virtual particles whereas material space-time sheets would represent real particles. The localization to zero modes occurring in each quantum jump would mean a selection of single component of this kind in the state created by the quantum field. Although the assignment of a genuine quantum field to material and mindlike space-time sheets might be un-necessary and impossible, the analogy might provide an order of magnitude grasp about the probability for the final state space-time surfaces to contain mindlike space-time sheets.

It is impossible to decide about the fate of the idea of cognitive quantum field. If one however accepts the idea about cognitive quantum field it is natural to apply standard QFT thinking to the situation. An attractive idea is that QFT for mindlike space-time sheets are characterized by kind of effective Hamiltonian (having nothing to do with energy) and that the generation of mindlike space-time sheets could be described by an interaction Hamiltonian. Induced emission would be possible for mindlike space-time sheets and would mean that the presence of mindlike space-time sheets of given type enhances the probability that new mindlike space-time sheets of same type are generated. Induced emission would make possible Bose-Einstein condensation type phenomenon. Also coherent states of could be possible but if one assumes that the number of mindlike space-time sheets is fixed, these states are not possible.

If learning corresponds to a creation of mindlike space-time sheets of particular kind in brain of the learner learning could be seen at least metaphorically as Bose-Einstein condensation for mindlike space-time sheets induced by a seed formed by some critical number of cognitive space-time sheets. Bose-Einstein condensation in the length scale of entire Earth is required by the learning at the level of species.

This is not so unrealistic requirement as it sounds first. The quanta of quantum fields correspond by Uncertainty Principle to topological field quanta of size given by the wave length associated with the quantum. Thus low energy quanta have very large size. In fact, the sizes of the topological field quanta associated with EEG frequencies are of same size as Earth and there is strong interaction between brain and Schumann resonances associated with the electromagnetic field in the wave cavity formed by the region between Earth's surface and ionosphere!

Of course, it might be that quantum coherence in this length scale is an unrealistic requirement. This would support the need to distinguish between quantal and classical morphic fields. The changes of the order parameters taking place in the scale of even Earth could make possible phase transitions generating Bose-Einstein condensates of quantum morphic fields identified as mindlike space-time sheets. The coupling constants appearing in the 'Hamiltonian' characterizing mindlike space-time sheets would depend on order parameters and this could unify the two mechanisms of collective learning.

The correlation between order parameters and states of quantum phases associated with mindlike space-time sheets could be one-one. The hypothesis that various macroscopic quantum phases are fixed by the values of zero modes is one basic working hypothesis of TGD inspired theory of consciousness and an attractive generalization of this hypothesis is that the values of zero modes also fix the macroscopic quantum phases associated with mindlike space-time sheets.

5.3 'Alike likes alike' rule

One of the basic hypothesis of Sheldrake's theory is 'alike likes alike': learning induces learning only in the members of *same* species. The explanation could be trivial. Memes I like genes in that they are universal. The universality is strongly suggested by the fact that the dissipation associated with self-organization by quantum jumps serves as Darwinian selector of selves such that the resulting asymptotic selves depend only very weakly on the initial conditions. Thus the values of global zero modes could lead to the learning of similar skills at different parts of globe.

If global zero modes induce phase transitions making probable generation of Bose-Einstein condensates of possible quantum memes, one can indeed understand this kind of effect. Also global Bose-Einstein condensation of memes could explain the effect. Perhaps the topological field quanta associated with em radiation fields generated by EEG currents could give rise to global Bose-Einstein condensate of memes.

How the meme (mindlike space-time sheet) is realized as habit depends on what kind of material space-time sheet mindlike space-time sheet is glued and what kind of combination if formes with other memes. Same quantum meme could lead to quite different habits when glued to the brain of a squirrel and human.

5.4 Learning of language as a morphic resonance?

Sheldrake represents the learning of language as a good example of morphic resonance.

Occasionally people invent new words, but basically, once we've assimilated it, it happens automatically. I don't have to think when I'm speaking, reaching for the next word. It just happens, and the same is true about physical skills, like riding a bicycle, or swimming, or skiing if you can ski, these kinds of things. So I think the more often these things happen the easier they become for people to learn. Things like learning language have happened over- well, we don't know how long human language has been around, at least 50,000 years, so there's a tremendously well-established morphic field for language-speaking. Each particular language has its own field which is usually established over centuries at least.

The easiness of children to learn language could indeed have explanation in terms of morphic resonance. The strong quantum entanglement between child and parents, especially mother, could make the morphic resonance possible. Bose-Einstein condensation of the 'linguistic' association sequences in the brain of the child induced by the Bose-Einstein condensate of linguistic association sequences in the brains of parents could induce language learning. One can of course wonder why it is so difficult for older people to learn language. Do we force us to learn the language at reflective level although it could occur at proto-level also. We learn rules but find difficult to apply them whereas child learns to apply the rules without learning the rules themselves. Are we far from criticality so that large fluctuations leading to the generation of the new level of self-organization are not possible anymore? Or, accepting the BE condensation model, is the reason simply that the linguistic association sequences have already BE condensed to form the habit corresponding to the native language?

5.5 Concepts as living creatures?

Sheldrake's ideas suggest that species represents kind of higher level consciousness. The notion of Mother Gaia suggest the same. One might consider even the possibility that abstract concept like 'mathematics' is not a mere abstraction but a living being formed by association sequences representing mathematical thoughts! This would explain why science really develops despite the fact that individual scientists know practically nothing of even their own branch of science and have no possibility to personally judge whether they can really trust to what they read from a scientific journal.

The concept of self naturally leads to just this kind of prediction. There is infinite hierarchy of selves and the very natural assumption that the experience of self X is 'sum' of the experiences of its subselves X_i abstracted so that some kind of average over the experiences $\langle X_{ij} \rangle$ over sub-subselves is formed gives rise to infinite hierarchy of abstractions. Our thoughts are our subselves and we ourselves are thoughts of higher level selves. For instance, the phenomenon of after mental images (for instance, visual after images) demonstrates that the selves representing our mental images wake up periodically just as we do. At the top of the hierarchy is entire universe having extremely abstracted experience determined by its subselves and having infinite memory. Interestingly, Stan Grof has reported about the altered states of consciousness in which subject person literally identifies with some concept: say what it is to be, not an individual mother, but all mothers of the world.

5.6 The origin of creativity

Sheldrake notices that morphic resonance and morphic fields are not all what is needed to understand evolution.

The whole idea of morphic resonance is evolutionary, but morphic resonance only gives the repetitions. It doesn't give the creativity. So evolution must involve an interplay of creativity and repetition. Creativity gives new forms, new patterns, new ideas, new art forms. And we don't know where creativity comes from. Is it inspired from above? Welling up from below? Picked up from the air? What? Creativity is a mystery wherever you encounter it, in the human realm, or in the realm of biological evolution, or of cosmic evolution. We know creativity happens. And then what happens is a kind of Darwinian natural selection. Not every good idea survives. Not every new form of art is repeated. Not every new potential instinct is successful. Only the successful ones get repeated. By natural selection and then through repetition they become probable, more habitual.

In TGD Universe creativity is due to quantum jump, which serves as the basic iterative step of self-organization.

5.7 ELF selves, semitrance mechanism, and collective learning

The recent developments in the understanding of personal self hierarchy and communications between various levels of the self hierarchy provide new insights to Sheldrake's ideas and it seems that the hierarchy of collective selves is absolutely essential for understanding of what is usually called the 'cultural aspects' of consciousness.

The first development was related to what might be called spectroscopy of consciousness [I4, I5]. The work of the pioneers of bioelectromagnetism has demonstrated that ELF em fields with frequencies that are multiples of cyclotron frequencies of biologically important ions have pronounced effects on living matter. The effects occur at the harmonics of the cyclotron transition frequencies in the endogenous magnetic field $B_{end} = 2B_E/5 = .2$ Gauss, where $B_E = .5$ Gauss is the nominal value of the Earth's magnetic field. Quite generally the magnetic transition frequencies of ions and molecules (including DNA) belong to the same range as EEG frequencies.

The observed selection rules suggest strongly that macroscopic quantum states of ions in the the endogenous magnetic field B_{end} having size of at least cell size are in question (for the possible interpretation of B_{end} as the dark counterpart of the Earth's magnetic field see [M3]). This and the fact that the energy scale involved is ridiculously small, is in a dramatic conflict with what standard physics allows. Many-sheeted space-time concept however provides an explanation of these effects and supports the existence of an entire zoo of macroscopic quantum systems, typically ionic super conductors at non-atomic space-time sheets where the temperature is extremely low. One ends up to a general vision about how Josephson currents between various space-time sheets representing levels of self hierarchy control and coordinate the behavior or living matter.

The spectacular prediction is that our personal self hierarchy should contain 'ELF selves', which by Uncertainty Principle correspond to topological field quanta of em field and have size of order Earth's circumference. This obviously makes possible telepathic communications based on the formation of join along boundaries bonds between topological field quanta of the sender and receiver: communication means simply generation of mental images. One must also seriously consider the possibility that our ELF selves survive in the physical death and are what might be called our 'souls'.

Second development was the discovery of the notion of semitrance. Self hierarchy means the existence of an entire hierarchy of geometric and subjective memories with increasing time spans of memory. The natural idea is that higher level selves could somehow communicate their memories to us. Semitrance [N5, N6] indeed provides this kind of communication mechanism. During semitrance parts of brain are entangled with some higher level self. These selves can communicate their memories to that part of brain which is awake (communication means generation of mental images). Ancient men received these communications as sensory hallucinations ('God's voice'), very much like schizophrenics, whereas modern man experiences them as thoughts and emotions which are often 'hallucinatory' in the sense that they are not automatic reactions to the sensory input. The TGD based vision for the development of language and civilization modifies Jaynes's vision about bicameral man as a schizophrenic of modern society and relies on the notion of semitrance. Semitrance mechanism is extremely general and could be present in all length scales. For instance, semitrance could provide the inhabitants of cell societies (organisms) and protein societies (cells) with a personal self narrative (genetic determination of cell as self narrative!).

Semitrance is in fact tailor-made for the realization of the collective memory and collective learning. Higher level collective selves can indeed communicate to individuals new ideas and skills via semitrance mechanism so that the same ideas are discovered almost simultaneously all around the globe. What is surprising that this kind of learning is occurring all the time: just the fact that it is so common, hinders us from realizing its universality. If ELF selves are characterized by patterns of magnetic transition frequencies, then one can consider 'alike likes alike' rule as a resonance. ELF selves with same frequency patterns can fuse by join along boundaries bonds to larger ELF selves and resonance indeed occurs quite concretely. Note that also the ELF selves of the deceased members of the species could be also present and give rise to racial memory. This resonance mechanism could establish 'species selves' controlling and coordinating the behavior of the individuals.

In the [M2, M4, M5, K3] the idea that massless extremals (MEs) are involved with the mechanisms behind long term memories and qualia, is developed in detail. It turns out that the general vision is consistent with the speculations of Sheldrake. Even more, ULF (ultralow frequency) MEs responsible for long term episodal memories have time durations of order years and have therefore spatial sizes of order light years: the only possible conclusion is that human consciousness is in tight interaction with electromagnetic life forms having cosmic size scale.

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