Article

Quantum Model for the Direct Currents of Becker

Matti Pitkänen [1]

1 Introduction

Robert Becker [5] proposed on basis of his experimental work that living matter behaves as a semiconductor in a wide range of length scales ranging from brain scale to the scale of entire body. Direct currents flowing only in preferred direction would be essential for the functioning of living manner in this framework.

One of the basic ideas of TGD inspired theory of living matter is that various currents, even ionic currents, are quantal currents. The first possibility is that they are Josephson currents associated with Josephson junctions but already this assumption more or less implies also quantal versions of direct currents.

TGD inspired model for nerve pulse [2] assumed that ionic currents through the cell membrane are probably Josephson currents. If this is the case, the situation is automatically stationary and dissipation is small as various anomalies suggest. One can criticize this assumption since the Compton length of ions for the ordinary value of Planck constant is so small that magnetic flux tubes carrying the current through the membrane look rather long in this length scale. Therefore either Planck constant should be rather large or one should have a non-ohmic quantum counterpart of a direct current in the case of ions and perhaps also protons in the case of neuronal membrane: electronic and perhaps also protonic currents could be still Josephson currents. This would conform with the low dissipation rate.

In the following the results related to laser induced healing, acupuncture, and DC currents are discussed first. The obvious question is whether these direct currents are actually currents and whether they could be universal in living matter. A TGD inspired model for quantal direct currents is proposed and its possible implications for the model of nerve pulse are discussed.

Whether the model for quantum direct currents is consistent with the proposed vacuum extremal property of the cell membrane [2] remains an open question but both options explain the special role of Ca^{++} currents and current of Na^{+} Cooper pairs in the generation of nerve pulse as in would take place in TGD Universe. In fact, it is not clear what one exactly means with the vacuum extremal property of cell membrane. Many-sheeted space-time allows to consider space-time sheets which can be both almost vacuum extremals and far from vacuum extremals. Also space-time sheets for which Planck constant is so large that both electronic and protonic Josephson currents become possible. Various pumps and channels could actually correspond to magnetic flux tubes along which various ionic supra currents or even Josephson currents can flow. The condition that both electronic and protonic supra currents are possible in same length scale leads to the hierarchy of Planck constants coming approximately as powers of $m_p/m_e \simeq 2^{11}$ proposed originally as a general truth. Radiation at Josephson frequency serves as a signature for Josephson currents.

In the following a TGD inspired quantum model for the direct currents of Becker as direct quantum currents is developed and shown to be consistent with what is known about nerve pulse generation. The model of nerve pulse based on this model is discussed in [2].

[1] Correspondence: Matti Pitkänen http://tgdtheory.com/. Address: Köydenpunojankatu 2 D 11 10940, Hanko, Finland. Email: matpitka@luukku.com.

2 Connection between laser induced healing, acupuncture, and association of DC currents with the healing of wounds

The findings of Robert Becker (the book "Electromagnetism and Life" by Becker and Marino can be found from web [5]) meant a breakthrough in the development of bioelectromagnetics. One aspect of bioelectromagnetic phenomena was the discovery of Becker that DC currents and voltages play a pivotal role in various regeneration processes. Why this is the case is still poorly understood and Becker's book is a treasure trove for anyone ready to challenge existing dogmas. The general vision guiding Becker can be summarized by a citation from the introduction of the book.

Growth effects include the alteration of bone growth by electromagnetic energy, the restoration of partial limb regeneration in mammals by small direct currents, the inhibition of growth of implanted tumors by currents and fields, the effect upon cephalocaudal axis development in the regenerating flatworm in a polarity-dependent fashion by applied direct currents, and the production of morphological alterations in embryonic development by manipulation of the electrochemical species present in the environment. This partial list illustrates the great variety of known bioelectromagnetic phenomena.

The reported biological effects involve basic functions of living material that are under remarkably precise control by mechanisms which have, to date, escaped description in terms of solution biochemistry. This suggests that bioelectromagnetic phenomena are fundamental attributes of living things ones that must have been present in the first living things. The traditional approach to biogenesis postulates that life began in an aqueous environment, with the development of complex molecules and their subsequent sequestration from the environment by membranous structures. The solid-state approach proposes an origin in complex crystalline structures that possess such properties as semiconductivity, photoconductivity, and piezoelectricity. All of the reported effects of electromagnetic forces seem to lend support to the latter hypothesis.

2.1 Observations relating to CNS

The following more quantitative findings, many of them due to Becker, are of special interest as one tries to understand the role of DC currents in TGD framework.

1. CNS and the rest of perineural tissue (tissue surrounding neurons including also glial cells) form a dipole like structure with neural system in positive potential and perineural tissue in negative potential. There is also an electric field along neuron in the direction of nerve pulse propagation (dendrites correspond to - and axon to +) (note that motor nerves and sensory nerves form a closed loop). Also microtubules within axon carry electric field and these fields are probably closely related by the many-sheeted variants of Gauss's and Faraday's laws implying that voltages along two different space-time sheets in contact at two points are same in a static situation.

2. A longitudinal potential along front to back in brain with frontal lobes in negative potential with respect to occipital lobes and with magnitude of few mV was discovered. The strength of the electric field correlates with the level of consciousness. As the potential becomes weaker and changes sign, consciousness is lost. Libet and Gerard observed traveling waves of potentials across the cortical layers (with speeds of about 6 m/s: TGD inspired model of nerve pulse predicts this kind of waves [2]). Propagating potentials were discovered also in glial cells. The interpretation was in terms of electrical currents.

3. It was found that brain injury generated positive polarization so that the neurons ceased to function in an area much larger than the area of injury. Negative shifts of neuronal potentials were associated with incoming sensory stimuli and motor activity whereas sleep was associated with a positive shift. Very small voltages and currents could modulate the firing of neurons without affecting the resting potential. The "generating" potentials in sensory receptors inducing nerve pulse were found to

be graded and non-propagating and the sign of the generating potential correlated with sensory input (say increase/reduction of pressure). Standard wisdom about cell membrane has difficulties in explaining these findings.

4. The natural hypothesis was that these electric fields are accompanied by DC currents. There are several experimental demonstrations for this. For instance, the deflection of assumed DC currents by external magnetic field (Hall effect) was shown to lead to a loss of consciousness.

2.2 Observations relating to regeneration

The second class of experiments used artificial electrical currents to enhance regeneration of body parts. These currents are nowadays used in clinical practice to induce healing or retard tumor growth. Note that tissue regeneration is a genuine regeneration of an entire part of organism rather than mere simple cell replication. Salamander limb generation is one of the most studied examples. Spontaneous regeneration becomes rare at higher evolutionary levels and for humans it occurs spontaneously only in the fractures of long bones.

1. An interesting series of experiments on Planaria, a species of simple flatworm with a primitive nervous system and simple head-to-tail axis of organization, was carried out. Electrical measurements indicated a simple head-tail dipole field. The animal had remarkable regenerative powers; it could be cut transversely into a number of segments, all of which would regenerate a new total organism. The original head-tail axis was preserved in each regenerate, with that portion nearest the original head end becoming the head of the new organism. The hypothesis was that the original head-tail electrical vector persisted in the cut segments and provided the morphological information for the regenerate. The prediction was that the reversal of the electrical gradient by exposing the cut surface to an external current source of proper orientation should produce some reversal of the head-tail gradient in the regenerate. While performing the experiment it was found found that as the current levels were increased the first response was to form a head at each end of the regenerating segment. With still further increases in the current the expected reversal of the head-tail gradient did occur, indicating that the electrical gradient which naturally existed in these animals was capable of transmitting morphological information.

2. Tissue regeneration occurs only if some minimum amount of neural tissue is present suggesting that CNS plays a role in the process although the usual neural activity is absent. The repeated needling of the stump had positive effect on regeneration and the DC current was found to be proportional to innervation. Hence needling seems to stimulate innervation or at least inducing formation of DC currents. Something like this might occur also in the case of acupuncture.

3. Regeneration involves de-differentiation of cells to form a blastema from which the regenerated tissue is formed. Quite early it was learned that carcinogens induce de-differentiation of cells because of their steric properties and by making electron transfer possible and that denervation induces tumor formation. From these findings Becker concluded that the formation of blastema could be a relatively simple process analogous to tumor growth whereas the regeneration proper is a complex self-organization process during which the control by signals from CNS are necessary and possibly realized in terms of potential waves.

4. Regeneration is possible in salamander but not in frog. This motivated Becker and collaborators to compare these situations. In an amputated leg of both salamander and frog the original negative potential of or order -1 mV went first positive value of order +10 mV. In frog it returned smoothly to its original value without regeneration. In salamander it returned during three days to the original base line and then went to a much higher negative value around -20 mV (resting potential is around -70 mV) followed by a return to the original value as regeneration had occurred. Thus the large

negative potential is necessary for the regeneration and responsible for the formation of blastema. Furthermore, artificial electron current induced regeneration also in the case of frog and in even in the denervated situation. Thus the flow of electrons to the stump is necessary for the formation of blastema and the difference between salamander and frog is that frog is not able to provide the needed electronic current although positive potential is present.

5. It was also learned that a so called neural epidermic junction (NEJ) formed in the healing process of salamander stump was responsible for the regeneration in the presence of nervation. The conclusion was that the DC voltage and electronic current relevant for regeneration can be assigned the interface between CNS and tissue rather than with the entire nerve and regeneration seems to be a local process, perhaps a feed of metabolic energy driving self-organization. Furthermore, NEJ seems to make possible the flow of electrons from CNS to the stump.

6. The red blood cells of animals other than mammals are complete and possess thus nuclei. Becker and collaborators observed that also red blood cells dedifferentiated to form blastema. Being normally in a quiescent state, they are ideal for studying de-differentiation. It was found that electric current acted as a trigger at the level of cell membrane inducing de-differentiation reflected as an increased amount of mRNA serving as signal for gene expression. Also pulsed magnetic field was found to trigger the de-differentiation, perhaps via induced electric field. By the way, the role of the cell membrane fits nicely with the view about DNA-cell membrane system as topological quantum computer with magnetic flux tubes connecting DNA and cell membrane serving as braids.

7. The experiments of Becker and collaborators support the identification of the charge carriers of DC currents responsible for the formation of large negative potential of stump as electrons. The test was based on the different temperature dependence of electronic and protonic conductivities. Electronic conductivity increases with temperature and protonic conductivity decreases and an increase was observed. In TGD based model also super-conducting charge carriers are possible and this finding does not tell anything about them.

2.3 Gene activation by electrostatic fields?

The basic question concerns the method of activation. The discovery of chemists Guido Ebner and Guido Schuerch [4] raises the hope that these ideas might be more than over-active imagination and their work also provides a concrete proposal for the activation mechanism. Ebner and Schuerch studied the effect of electrostatic fields on the growth and morphogenesis of various organisms. Germ, seeds, or eggs were placed between conducting plates creating an electric field in the range .5-2 kV/m: note that the Earth's electric field is in the range $.1 - 4$ kV/m and of the same order of magnitude.

The outcome was rather surprising and in the year 1989 their employer Ciba Geigy (now Novaris) applied for a patent "Method of enhanced fish breeding" [4] for what is called Ciba Geigy effect. The researchers describe how fishes (trouts) develop and grow much better, if their eggs have been conditioned in an electrostatic field. The researchers report [4] that also the morphology of the fishes was altered to what seems to represent an ancient evolutionary form: this was not mentioned in the patent.

The chemists founded their own Institute of Pharmaceutical Research near Basel, where Guido Ebner applied for another very detailed patent, which was never granted (it is not difficult to guess the reasons why!). In the patent he describes the effect of electrostatic fields on several life forms (cress, wheat, corn, fern, micro-organisms, bacteria) in their early stage of development. A clear change in the morphogenesis was observed. For instance, in one example fern had all sort of leaves in single plant apparently providing a series of snapshots about the evolution of the plant. The evolutionary age of the first leaf appeared to be about 300 million years whereas the last grown-up leaf looked close to its recent form.

If one takes these finding seriously, one must consider the possibility that the exposure to an electrostatic field can activate passive genes and change the gene expression so that older morphologies are

expressed. The activation of not yet existing morphologies is probably more difficult since strong consistency conditions must be satisfied (activation of program requires activation of a proper hardware). This would suggest that genome is a kind of archive containing also older genomes even potential genomes or that topological quantum computer programs [1] determine the morphology to certain extent and that external conditions such as electric field determine the self-organization patters characterizing these programs.

It is known that the developing embryo has an electric field along the head-tail axis and that this field plays an important role in the control of growth. These fields are much weaker than the fields used in the experiment. p-Adic length scale hierarchy however predicts an entire hierarchy of electric fields and living matter is indeed known to be full of electret structures. The strength of the electric field in some p-adic length scale related to DNA might somehow serve as the selector of the evolutionary age. The recapitulation of phylogeny during the ontogeny could mean a gradual shift of the activated part of the memone, perhaps assignable to tqc programs, and be controlled by the gradually evolving electric field strength.

The finding that led Ebner to his discovery was that it was possible to "wake up" ancient bacteria by an exposure to an electrostatic field. The interpretation would be in terms of loading of metabolic batteries. This would also suggest that in the case of primitive life forms like bacteria the electric field of Earth has served as metabolic energy source whereas in higher life forms endogenous electric fields have taken the role of Earth's electric field.

2.4 A TGD based model for the situation

On basis of these observations one can try to develop a unified view about the effects of laser light, acupuncture, and DC currents. It is perhaps appropriate to start with the following - somewhat leading - questions inspired by a strong background prejudice that the healing process - with control signals from CNS included - utilizes the loading of many-sheeted metabolic batteries by supra currents as a basic mechanism. In the case of control signals the energy would go to the "moving of the control knob".

1. Becker assigns to the system involved with DC currents an effective semiconductor property. Could the effective semiconductor property be due the fact that the transfer of charge carriers to a smaller space-time sheet by first accelerating them in electric field is analogous to the transfer of electrons between conduction bands in semiconductor junction? If so, semiconductor property would be a direct signature of the realization of the metabolic energy quanta as zero point kinetic energies.

2. Supra currents flowing along magnetic flux tubes would make possible dissipation free loading of metabolic energy batteries. This even when oscillating Josephson currents are in question since the transformation to ohmic currents in semiconductor junction makes possible energy transfer only during second half of oscillation period. Could this be a completely general mechanism applying in various states of regeneration process. This might be the case. In quantal situation the metabolic energy quanta have very precise values as indeed required. For ohmic currents at room temperature the thermal energies are considerably higher than those corresponding to the voltage involved so that they seem to be excluded. The temperature at magnetic flux tubes should be however lower than the physiological temperature by a factor of order 10^{-2} at least for the voltage of -1 mV. This would suggest high T_c super-conductivity is only effective at the magnetic flux tubes involved. The finding that nerve pulse involves a slight cooling of the axonal membrane proposed in the TGD based model of nerve pulse [2] to be caused by a convective cooling due the return flow of ionic Josephson currents would conform with this picture.

3. What meridians are and what kind of currents flow along them? Could these currents be supra currents making possible dissipation-free energy transfer in the healthy situation? Does the negative potential of order -1 mV make possible flow of protonic supra currents and loading of metabolic

batteries by kicking protons to smaller space-time sheets? Could electronic supra currents in opposite direct induce similar loading of metabolic batteries? Could these tow miniature metabolisms realize control signals (protons) and feedback (electrons)?

The model answering these questions relies on following picture. Consider first meridians.

1. The direct feed of metabolic energy as universal metabolic currencies realized as a transfer of charge carriers to smaller space-time sheets is assumed to underly all the phenomena involving healing aspect. Meridian system would make possible a lossless metabolic energy feed - transfer of "Chi" - besides the transfer of chemically stored energy via blood flow. The metabolic energy currencies involved are very small as compared to .5 eV and might be responsible only for "turning control knobs". The correlation of the level of consciousness with the overall strength of DC electric fields would reduce to the level of remote metabolic energy transfer.

2. The model should explain why meridians have not been observed. Dark currents along magnetic flux tubes are ideal for the energy transfer. If the length of the superconducting "wire" is long in the scale defined by the appropriate quantum scale proportional to $\hbar$, classical picture makes sense and charge carriers can be said to accelerate and gain energy ZeV. For large values of $\hbar$ an oscillating Josephson current would be in question. The semiconductor like structure at the end of meridian -possibly realized in terms of pair of space-time sheets with different sizes- makes possible a net transfer of metabolic energy even in this case as pulses at each half period of oscillation. The transfer of energy with minimal dissipation would thus explain why semiconductor like property is needed and why acupuncture points have high value of conductivity. The identification of meridians as invisible magnetic flux tubes carrying dark matter would explain the failure to observe them: one further direct demonstration for the presence of dark matter in biological systems.

3. In the case of regeneration process NEJs would be accompanied by a scaled down version of meridian with magnetic flux tubes mediating the electronic Josephson current during blastema generation and protonic supra current during the regeneration proper. Space-time sheets of proton *resp.* electron correspond to k_p and $k_e = k_p + 11$. In a static situation many-sheeted Gauss law in static situation would guarantee that voltages over NJE are same.

4. One can of course worry about the smallness of electrostatic energies ZeV as compared to the thermal energy. Zero point kinetic energy could correspond also to the magnetic energy of the charged particle. For sufficiently large values of Planck constant magnetic energy scale is higher than the thermal energy and the function of voltage could be only to drive the charged particles along the flux tubes to the target: and perhaps act as a control knob with electrostatic energy compensating for the small lacking energy. Suppose for definiteness magnetic field strength of $B = .2$ Gauss explaining the effects of ELF em fields on brain and appearing in the model of EEG. Assume that charged particle is in minimum energy state with cyclotron quantum number $n = 1$ and spin direction giving negative interaction energy between spin and magnetic field so that the energy is $(g-2)\hbar eB/2m_p$. Assume that the favored values of hbar correspond to number theoretically simple ones expressible as a product of distinct Fermat primes and power of 2. In the case of proton with $g \simeq 2.7927$ the standard metabolic energy quantum $E_0 = .5$ eV would require roughly $\hbar/\hbar_0 = 17 \times 2^{34}$. For electron $g - 2 \simeq \alpha/\pi \simeq .002328$ gives $\hbar/\hbar_0 = 5 \times 17 \times 2^{30}$.

Consider next NEJs and semiconductor like behavior and charging of metabolic batteries.

1. Since NEJ seems resembles cell membrane in some respects, the wisdom gained from the model of cell membrane and DNA as tqc can be used. The model for nerve pulse and the model for DNA as topological quantum computer suggest that dark ionic currents flowing along magnetic flux tubes characterized by a large value of Planck constant are involved with both meridians and NJEs and might even dominate. Magnetic flux tubes act as Josephson junctions generating oscillatory supra

currents of ions and electrons. For large values of $\hbar$ also meridians are short in the relevant dark length scale and act as Josephson junctions carrying oscillatory Josephson currents.

2. The findings of Becker suggest that acu points correspond to sensory receptors which are normally in a negative potential. The model for the effects of laser light favors (but only slightly) the assumption that in a healthy situation it is protons arriving along magnetic flux tubes which are kicked to the smaller space-time sheets and that negative charge density at acu point attracts protons to the acu point. Electrons could of course flow in reverse direction along their own magnetic flux tubes and be kicked to the smaller space-time sheets at the positive end of the circuit. In the case of brain, protonic end would correspond to the frontal lobes and electronic end to the occipital lobes. This kind of structure could appear as fractally scaled variants. For instance, glial cells and neurons could form this kind of pair with neurons in negative potential and glial cells in positive potential as suggested by the fact that neuronal damage generates positive local potential.

3. Classically the charge carriers would gain energy $E = ZeV$ as they travel along the magnetic flux tube to NJE. If this energy is higher than the metabolic energy quantum involved, it allows the transfer of charge carrier to a smaller space-time sheet so that metabolic resources are regenerated. Several metabolic quanta could be involved and the value of $V(t)$ would determine, which quantum is activated. The reduction of the V below critical value would lead to a starvation of the cell or at least to the failure of control signals to "turn the control knob". This should relate to various symptoms like pain at acupuncture points. In a situation requiring acupuncture the voltage along flux tubes would be so small that the transfer of protons to the smaller space-time sheets becomes impossible. As a consequence, the positive charge carriers would accumulate to the acu point and cause a further reduction of the voltage. Acupuncture needle would create a "wound" stimulating large positive potential and the situation would be very much like in regeneration process and de-differentiation induced by acupuncture could be understood.

Many questions remain to be answered.

1. What causes the de-differentiation of the cells? The mere charging of metabolic energy batteries perhaps? If so then the amount of metabolic energy- "chi"- possessed by cell would serve as a measure for the biological age of cell and meridian system feeding "chi" identified as dark metabolic energy would serve as a rejuvenating agent also with respect to gene expression. Or does the electric field define an external energy feed to a self-organizing system and create an electromagnetic environment similar to that prevailing during morphogenesis inducing a transition of cells to a dedifferentiated state? Or could DNA as tqc allow to understand the modification of gene expression as being due to the necessity to use tqc programs appropriate for regeneration? Or should cells and wounded body part be seen as intentional agents doing their best to survive rather than as passive parts of biochemical system?

2. Acupuncture and DC current generation are known to induce generation of endorphins. Do endorphins contribute to welfare by reducing the pain or do they give a conscious expression for the fact that situation has improved as a result of recharging of the metabolic energy batteries?

3. Could the continual charging of metabolic energy batteries by DC currents occur also in the case of cell membrane? The metabolic energy quantum would be around .07 eV in this case and correspond to p-adic length scale $k = 140$ for proton (the quantum is roughly a fraction 1/8 of the fundamental metabolic energy quantum .5 eV corresponding to $k = 137$).

3 Quantum model for effective semiconductor property

Becker [5] summarizes his findings by stating that living matter is effective semiconductor. There are pairs of structures in positive and negative potential in various scales and the current between the plates

of this effective capacitor flows when above some minimum potential difference. The current flows from positive to negative pole and could be electron current. Also proton current in opposite direction can be considered but electron current is experimentally favored. For instance consciousness is lost when magnetic field is used to deflect the current.

In TGD framework natural carriers of these currents would be magnetic flux tubes carrying also electric fields. A very simple deformation of the imbeddings of constant longitudinal magnetic fields gives also longitudinal electric field. With a slight generalization one obtains helical electric and magnetic fields. A crucial difference is that these currents would be quantal rather than ohmic currents even in the length scale of biological body and even longer scales assignable to the magnetic body.

The following argument allows to understand the physical situation.

1. A precise everyday analogy is vertical motion in the gravitational field of Earth between surface and some target at given height h. If the kinetic energy is high enough, the particle reaches the target. If not, the particle falls back. In quantum case one expects that the latter situation corresponds to very small probability amplitude at the target (tunneling to classically forbidden kinematic region).

2. Now electric field replaces gravitational field. Suppose that the classical electric force experienced by the particle is towards the capacitor plate taking the role of the surface of Earth. Below critical field strength the charged particle cannot reach the target classically and quantum mechanically this occurs only by tunneling with vanishingly small probability.

3. Particles with opposite value of charge experience force which accelerates them and classically they certainly reach the second plate. What happens in quantum situation? It seems that this situation is essentially identical with the first one: one has linear potential in finite interval and wave functions are localized in this range. One can equivalently regard these states as localize near the second capacitor plate.

4. A good analogy is provided by atoms: classically electron would end down to the nucleus but quantization prevents this. Also now one can imagine stationary solutions for which the electric currents for individual charges vanish at the plates although classically there would be a current in another direction. Also quantum mechanically non-vanishing conserved current is possible: all depends on boundary conditions.

3.1 Basic model

Consider now the situation at more quantitative level.

1. One can assign complex order parameters Ψ_k to various Bose-Einstein condensates of supra phases and obey Schrödinger equation

$$i\partial_t \Psi_k \quad = \quad (-\frac{\hbar^2}{2m_k}\partial_z^2 + q_k E z)\Psi_k \quad . \tag{3.1}$$

   Here it is assumed that the situation is effectively one-dimensional. E is the value of constant electric field.

2. The Schrödinger equation becomes non-linear, when one expresses the electric field in terms of the total surface charge density associated with the plates of effective capacitor. In absence of external electric field it is natural to assume that the net surface charge densities σ at the plates are of opposite sign so that the electric field inside the capacitor is proportional to

$$\sigma \quad = \quad E = \sum \sigma_i = \sum_i q_i \overline{\Psi}_i \Psi_i \quad . \tag{3.2}$$

This gives rise to a non-linear term completely analogous to that in non-linear Schrödinger equation. A more general situation corresponds to a situation in which the region interval $[a, b]$ bounded by capacitor plates a and b belongs to a flux longer tube like structure $[A, B]$: $[a, b] \subset [A, B]$. In this case one has

$$E_{tot} \quad = \quad E + E_0 \quad . \tag{3.3}$$

This option is needed to explain the observations of Becker that the local strengthening of electric field increases the electron current: this would be the case in the model to be discussed if this field has a direct opposite to the background field E_0. One could also interpret E as quantized part of the electric field and E_0 as classical contribution.

3. The electric currents are given by

$$j_k \quad = \quad \frac{i\hbar q_k}{2m_k} \overline{\Psi}_k \partial_z^{\leftrightarrow} \Psi_k \quad . \tag{3.4}$$

In stationary situation the net current must vanish:

$$\sum_k j_k \quad = \quad 0 \quad . \tag{3.5}$$

A stronger condition is that individual currents vanish at the plates:

$$j_k \quad = \quad 0 \quad . \tag{3.6}$$

It must be emphasized that this condition does not make sense classically.

3.2 Explicit form of Schrödinger equation

Consider now the explicit form of Schrödinger equation in given electric field.

1. The equation is easy to solve by writing the solution ansatz in polar form (the index k labelling the charge particle species will be dropped for notational convenience).

$$\Psi \quad = \quad R(aexp(iU) + bexp(-iU))exp(-iE_n t) \tag{3.7}$$

For real solutions current vanishes identically and this is something which is not possible classically. It is convenient to restrict the consideration to stationary solutions, which are energy eigen states with energy value E_n and express the general solution in terms of these.

2. The Schrödinger equation reduces with the change of variable

$$\begin{aligned} z &\rightarrow \frac{(z-z_0)}{z_1} \equiv x \ , \\ z_0 &= \frac{E_n}{qE} \ , \ z_1 = (\frac{\hbar^2}{2mqE})^{1/3} \ . \end{aligned} \tag{3.8}$$

to

$$(\partial_x^2 + x)\Psi = 0 \ . \tag{3.9}$$

The range $[0, z_0]$ for z is mapped to the range $[-z_0/z_1, 0]$. z_0/z_1 has positive sign as is easy to verify. The value range of x is therefore negative irrespective of the sign of qE. This is equation for Airy functions [3]. Airy functions are encounterd in WKB approximation in the approximation that potential function is linear. These functions appear also in the model of rainbow.

The change of variable leads automatically to solutions restricted near the plate where the situation is completely analogous to that in gravitational field of Earth. For stationary solutions test charge in a given background field would be localized near capacitor plate with opposite sign of charge. A strong background field could be created by charges which do not correspond to the ionic charges defining ionic currents. Electrons and protons could define this field possibly associated with flux tubes considerably longer than the distance between capacitor plates.

3. Using the polar representation $\Psi = Rexp(iU)$ Schrödinger equation reduces to two equations

$$\begin{aligned} \left[(\partial_x^2 - U_x^2 + x)R\right] cos(U) &+ \left[U_{xx} + 2\partial_x R \partial_x U\right] sin(U) = 0 \ , \\ \left[(\partial_x^2 - U_x^2 + x)R\right] sin(U) &- \left[U_{xx} - 2\partial_x R \partial_x U\right] cos(U) = 0 \ . \end{aligned} \tag{3.10}$$

Note that both (R, U) and $(R, -U)$ represent solutions for given value of energy so that the solution can be chosen to be proportional to $cos(U)$ or $sin(U)$. The electric current j is conserved and equal to the current at $x = 0$ and given by

$$j = \frac{\hbar}{2m}\frac{U_x}{z_1}R^2 \ , \ z_1 = (\frac{\hbar}{2mqE})^{1/3} \ . \tag{3.11}$$

The current vanishes if either U_z is zero or if the solution is of form $\Psi = Rsin(U)$.

3.3 Semiclassical treatment

In semiclassical approximation potential is regarded as so slowly varying that it can be regarded as a constant. In this situation one can write the solution of form $Rexp(iU)$ as

$$\Psi = R_0 exp\left(\frac{i}{\hbar}\int_0^z \sqrt{2m}\sqrt{E - qEz}dz\right) = R_0 exp\left(i\int_0^x x^{1/2}dx\right) \ . \tag{3.12}$$

The plate at which the initial values are given can be chosen so that the electric force is analogous to gravitation at the surface of Earth. This requires only to replaced coordinate z with a new one vanishing at the plate in question and gives to the energies a positive shift $E_0 = qE_0h$.

1. The semiclassical treatment of the equation leads to Bohr rules

$$\frac{\oint p_z dz}{\hbar} = \frac{2}{\hbar}\int_0^h p_z dz = n \ . \tag{3.13}$$

This gives

$$\frac{\oint p_z dz}{\hbar} = \frac{2\sqrt{2m}}{\hbar}\int_0^h \sqrt{E_n - qEz}dz = 2\int_0^{x_0} x^{1/2} = \frac{4}{3}x_0^{3/2} = n \ . \tag{3.14}$$

Note that the turning point for classical orbit corresponds to $z_{max} = E_n/qE$.

2. One obtains

$$E_n = \frac{1}{2}(\frac{nqE\hbar^2}{r\sqrt{m}})^{2/3} \ , \ r = \int_0^1 (1-u)^{1/2}du = \frac{2}{3} \ . \tag{3.15}$$

The value of z_{max} is

$$z_{max} = \frac{E_n}{qE} = \frac{n^{2/3}}{2r^{2/3}}(\frac{\hbar^2}{qEm})^{1/3} \ . \tag{3.16}$$

3. The approximation $R = R_0 = constant$ can make sense only if the position of the second plate is below z_{max}. This is possible if the value of n is large enough ($n^{2/3}$ proportionality), if the mass m of the charged particle is small enough ($m^{-1/3}$ proportionality raising electron and also proton to special position, or if the strength of electric field is small enough ($E^{-1/3}$ proportionality). The value z_{max} is proportional to $\hbar^{2/3}$ so that a phase transition increasing Planck constant can induce current flow.

3.4 Possible quantum biological applications

The proposed model for quantum currents could provide quantum explanation for the effective semiconductor property of DC currents of Becker.

1. The original situation would be stationary with no currents flowing. The application of external electric field in correct direction would reduce the voltage below the critical value and currents would start to flow. This is consistent with Becker's findings if there is background electric field E_0 so that the applied field has direction opposite to E_0 so that the field strength experienced by charged particles is reduced and it is easier for them to reach the second plate. This is of course a possible objection against the proposal.

2. Becker's DC currents appear in several scales. They are assigned with the pairs formed by CNS and perineural tissue (this includes also glia cells) and by frontal and occipital lobes. Acupuncture could involve the generation of a DC supra current. The mechanism would be essential in the healing. Also the mechanism generating qualia could involve generation of supra currents and dielectric breakdown for them. The role of the magnetic flux tubes in TGD inspired biology suggests that the mechanism could be universal. If this were the case one might even speak about Golden Road to the understanding of living matter at basic level.

Even the generation of nerve pulse might be understood in terms of this mechanism. One can argue that neurons have higher evolutionary level than the system pairs to which only electron currents or electron and proton currents can be assigned. This because the value of Planck constant is higher for the magnetic flux tubes carrying the quantal ionic currents.

1. For Bose-Einstein condensate the simplest choice is $n = 1$ at both plates. The energy eigenvalues would naturally differ by the shift $E_0 = qE_0h$ at the two plates for given particle type. Under these assumptions the current can flow appreciably only if the voltage is below the minimum value. This is certainly a surprising conclusion but brings in mind what happens in the case of neuronal membrane. Indeed, hyper-polarization has a stabilizing - something difficult to understand classically but natural quantum mechanically.

2. The reduction of membrane potential slightly below the resting potential generates nerve pulse. Also a phase transition increasing the value of Planck constant might give rise to quantal direct currents and generate flow of ionic currents giving rise to nerve pulse. Stationary solutions are located near either capacitor plate. What comes in mind is that nerve pulse involves a temporary change of the capacitor plate with this property.

3. If electron and proton currents flow as direct currents, one encounters a problem. Nerve pulse should begin with direct electronic currents and followed by direct protonic currents and only later ions should enter the game if at all. The existing model for nerve pulse however assumes that at least electrons flow as oscillating Josephson currents rather than direct quantal currents. This is quite possible and makes sense if the cell membrane thickness small - that is comparable to electron Compton length as assumed in large $\hbar$ model for the nerve pulse. This assumption might be necessary also for proton and would make sense if the Planck constant for protonic flux tubes is large enough. For ions the Compton length would be much smaller than the thickness of cell membrane and direct currents would be natural.

   If the Planck constant is same for biologically important ions, direct quantum currents would be generated in definite order since in $h < z_{max}$ one has $z_{max} \propto m^{-1/3} \propto A^{-1/3}$. The lightest ions would start to flow first.

   (a) Nerve pulses can generated by voltage gated channels for potassium and calcium. Voltage gated channels would correspond to magnetic flux tubes carrying electric field. For voltage gated channels Na^+ ions with atomic weight $A = 23$ and nuclear charge $Z = 11$ start to flow first, then K^+ ions with atomic weight $A = 39$ and $Z = 19$ follow. This conforms with the prediction that lightest ions flow first. The nerve pulse duration is of order 1 millisecond at most.

   (b) Nerve pulses can be also generated by voltage gated Ca^{+2} channels. In this case the duration can be 100 ms and even longer. Ca has $A = 40$ and $Z = 20$. The proper parameter is $x = r^2/qA$, $r = \hbar/\hbar_0$. One has

$$\frac{x(Ca^{++})}{x(Na^+)} = (\frac{r(Ca^{++}}{r_(Na^+)})^2 \times \frac{23}{2 \times 40} \quad . \tag{3.17}$$

   $r^2(Ca_{++}) \sim 2r^2(Na_+)$ would allow to compensate for the increased weight and charge of Ca_{++} ions.

4. The objection is that Na^+ and K^+ are not bosons and therefore cannot form Bose-Einstein condensates. The first possibility is that one has Cooper pairs of these ions. This would imply

$$\frac{x(Ca^{++})}{x(2Na^+)} = (\frac{r(Ca^{++}}{r_(Na^+)})^2 \times \frac{23}{20} \quad .$$

Ca^{++} and Na^+ pair would be in very similar position for a given value of Planck constant. This is a highly satisfactory prediction. Another manner to circumvent the problem is more science fictive and assumes that the Na^+ ions are exotic nuclei behaving chemically as Na^+ but having one charged color bond between nucleons.

It remains to be seen whether this model is consistent with the model of cell membrane as almost vacuum extremal or whether the vacuum extremal based model could be modified by treating ionic currents as direct currents. In the vacuum extremal model classical Z^0 gauge potential is present and would give a contribution to the counterpart of Schrödinger equation. The ratio $x(Ca^+ +)/x(2Na^+)$ for the parameter $x = r^2/q(A-Z)A$ (em charge q is replaced with neutron number in good approximation) equals to 1.38 and is not therefore very far from unity.

The many-sheetedness of space-time is expected to play a key role and one should precisely specify which sheets are almost vacuum extremals and which sheets are far from vacuum extremals. One expects that magnetic flux tubes are far from vacuum extremals and if voltage gated ionic channels are magnetic flux tubes, the proposed model might be consistent with the model of cell membrane as almost vacuum extremal.

4 The effects of ELF em fields on vertebrate brain

The effects of ELF em fields on vertebrate brain [6] occur both in frequency and amplitude windows. Frequency windows can be understood if the effect occur at cyclotron frequencies and correspond to absorption of large $\hbar$ photons. A finite variation width for the strength of magnetic field gives rise to a frequency window. The observed quantal character of these effects occurring at harmonics of fundamental frequencies leads to the idea about cyclotron Bose-Einstein condensates as macroscopic quantum phases. The above considerations support the assumption that fermionic ions form Cooper pairs.

I have tried to understand also the amplitude windows but with no convincing results. The above model for the quantum currents however suggests a new approach to the problem. Since ELF em fields are in question they can be practically constant in the time scale of the dynamics involved. Suppose that the massless extremal representing ELF em field is orthogonal to the flux tube so that the ions flowing along flux tube experience an electric force parallel to flux tube. What would happen that the ions at the flux tube would topologically condensed at both the flux tube and massless extremal simultaneously and experience the sum of two forces.

This situation is very much analogous to that defined by magnetic flux tube with longitudinal electric field and also now quantum currents could set on. Suppose that semiconductor property means that ions must gain large enough energy in the electric field so that they can leak to a smaller space-time sheet and gain one metabolic quantum characterized by the p-adic length scale in question. If the electric field is above the critical value, the quantum current does not however reach the second capacitor plate as already found: classically this is of course very weird. If the electric field is too weak, the energy gain is too small to allow the transfer of ions to smaller space-time sheet and no effect takes place. Hence one would have an amplitude window.

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