

DNA and time reversal

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Abstract

This article is devoted to the view about DNA inspired by zero energy ontology (ZEO) forming the basis of the quantum measurement theory of Topological Geometrodynamics (TGD) and by the notion of dark DNA inspired by the TGD view about dark matter as phases of the ordinary matter with effective Planck constant $h_{eff} = nh_0 > h$ at magnetic body (MB) - the third key notion distinguishing TGD from standard model. The basic prediction of ZEO is that "big" (ordinary) state function reduction (BSFR) changes the arrow of time meaning "death" and "reincarnation" with opposite arrow of time. This leads to a new view about self-organization.

The time reversals of the basic processes like transcription and replication turn out to be possible only for the conjugate (passive) strand - this is basically due to the CPT theorem in TGD context and chiral selection. By chiral selection enzymes can catalyze processes but not their time reversals. For instance, conjugate strand polymerizes in reverse time direction - this looks like depolymerization in standard time direction. Polymerization of the conjugate strand however occurs in standard time direction but in reverse direction along strand.

The recombination of DNA strands during meiosis is poorly understood. This could correspond to reconnections for the flux tubes associated with the active DNA strands. Time reversal would occur in BSFR and formerly passive conjugate DNA strands would depolymerize to "loose" codons (not independent letters) by the time reversed polymerization, the flux tubes associated with the formerly active strands would suffer reconnections inducing recombination without assistance of enzymes, second BSFR would occur, and be followed by the replication of recombined active strands.

According to the findings of Becker, the direction of the electric field along the body axis determines whether the system is awake or sleeps. By the properties of electric field under time reflection, the arrow of time correlates also with the direction of the electric field. TGD predicts that consciousness is possible even at

the level of DNA. Could also DNA have a longitudinal electric field with direction correlating with the arrow of time of DNA at the (magnetic body) MB of DNA. Could there be a switch changing the direction of this electric field?

This inspires a model for the DNA as ferroelectret based on the properties of the negatively charged sticky ends of chromosome and dark DNA codons as proton triplets along a magnetic flux tube parallel to DNA strand. A simple proposal for the time switch based on the analog of Becker's DC currents emerges: proton flow of the dark protons of sticky end to the opposite sticky end would change the arrow of time. The model could generalize also to proteins known to be ferro-electrets and could be accompanied also by their dark analogs.

1 Introduction

This article is devoted to the view about DNA inspired by (zero energy ontology) ZEO [Pitkänen 2020_a, [Pitkänen 2019_c] forming the basis of the quantum measurement theory of Topological Geometro-dynamics (TGD) [Pitkänen 2016_b, Pitkänen 2014_c] and by the notion of dark DNA [Pitkänen 2018_a] inspired by the TGD view about dark matter as phases of the ordinary matter with effective Planck constant $h_{eff} = nh_0 > h$ [Pitkänen 2017_a, Pitkänen 2015_c, Pitkänen 2017_e] at (magnetic body) MB [Pitkänen 2010, Pitkänen 2018_e, Pitkänen 2016_c, Pitkänen 2018_f] - the third key notion distinguishing TGD from standard model. The basic prediction of ZEO is that "big" (ordinary) state function reduction (BSFR) changes the arrow of time meaning "death" and "reincarnation" with opposite arrow of time. For dark matter at the MB the periods with a given arrow of time would be long and induce the long-lasting effective change of the arrow of time for the ordinary matter.

This leads to a new view about self-organization [Pitkänen 2019_d] involving in an essential manner time reversed dissipation looking like energy feed in the standard direction and quantum coherent MB as a master quantum controlling the ordinary matter. The energy feed is necessary since the increase of h_{eff} requires energy.

1.1 Time reversal and the dynamics of DNA

The time reversals of the basic processes like transcription and replication turn out to be possible only for the conjugate strand - this is basically due to the chiral selection and CPT theorem in TGD context. CPT C denotes charge conjugation, P spatial reflection, and T geometric time reflection to be distinguished from thermo-dynamical time reversal and time reversal occurring in BSFR. The triviality of C (matter-antimatter asymmetry) implies that T acts like P mapping molecules to their mirror images. By chiral selection enzymes can catalyze processes but not their time reversals. For instance, conjugate strand polymerizes in reverse time direction - this looks like depolymerization in standard time direction. Polymerization of the conjugate strand however occurs in standard time direction but in reverse direction along strand.

The recombination of DNA strands during meiosis is poorly understood. This could correspond to reconnections for the magnetic flux tubes associated with the active DNA strands. Time reversal would occur in BSFR and formerly passive conjugate DNA strands would depolymerize to "loose" codons [Pitkänen 2020_b] (not independent letters) by the time reversed polymerization, the flux tubes associated with the formerly active strands would suffer reconnections inducing recombination without assistance of enzymes, second BSFR would occur, and be followed by the replication of recombined active strands.

1.2 Does DNA have longitudinal electric field with direction correlating with the arrow of time?

According to the findings of Becker [Becker 1990_a, Becker 1990_b], the direction of the electric along the body axis field determines whether the system is awake or asleep. By the properties of electric field under time reflection, the arrow of time correlates also with the direction of the electric field. TGD predicts that consciousness is possible even at the level of DNA. Could also DNA have a longitudinal electric field with direction correlating with the arrow of time of DNA at the MB of DNA? Could there be a switch changing the direction of this electric field?

There is an inspiring analogy with microtubules, which are highly dynamical and carry a longitudinal electric field, whose strength correlates with the microtubule length [Trkal, Pkorny and Jelinek 1998, Trkal et al 1997]. Could sticky ends generate a longitudinal field along DNA double strand with strength determined by the lengths of the sticky ends?

In the standard picture the flux of the longitudinal electric field would be proportional to the difference of the negative charges associated with the sticky ends. In TGD framework DNA strands are accompanied by the dark analog of DNA with codons realized as 3-proton units neutralizing the negative charge of the ordinary DNA except at sticky ends.

A simple proposal for the time switch based on the analog of Becker's DC currents emerges: proton flow of the dark protons between sticky ends would change the arrow of time. The model could generalize also to proteins known to be ferro-electrets and accompanied also by their dark analogs.

2 DNA and time reversal

TGD inspired theory of consciousness based on ZEO [Pitkänen 2020_a] predicts that also DNA is a conscious system: actually TGD Universe is in a well-defined sense panpsychic. In a "big" (ordinary) state function (BSFR) system "dies" and "reincarnates" with a reversed arrow of time. The hierarchy of effective Planck constants $h_{eff} = nh_0$ [Pitkänen 2015_c] having a number theoretical interpretation [Pitkänen 2017_a] labels the phases of the ordinary matter behaving like dark matter and will be referred to as "dark

matter” in the sequel. Large values of h_{eff} make quantum coherence possible in arbitrarily long length and time scales.

The dark matter at the layers of the MB of the system (MB means a deviation from Maxwell’s electrodynamics) controls the ordinary bio-matter. Dark matter resides at the flux tubes carrying monopole flux not possible in the Maxwellian world. The TGD based model [Pitkänen 2014_d] identifies the negatively charged exclusion zones (EZs) generated in Pollack effect [Zhao, Pollack, Figueroa 2009] as regions from which part of protons transferred to flux tubes as dark protons. Applied to the water environment of DNA this leads to the notion of dark DNA as flux tubes carrying dark proton triplets representing genetic codons [Pitkänen 2018_a]. Also mRNA, aminoacids, and tRNA would have these representations. Dark DNA strands would accompany the ordinary DNA strands. The positive charge of the dark DNA and mRNA would screen the negative charge of ordinary DNA and stabilize it.

The attention is in the recent article in the dynamical processes associated with DNA. Could time reversal play a key role in various processes related to DNA. The basic process considered are DNA transcription and replication and meiosis and it is interesting to view them in ZEO. Could one imagine a switch inducing time reversal of DNA as a ”big” (ordinary) state function (BSFR) in the scale of entire DNA double strand + dark DNA double strand accompanying it?

2.1 Deassembly as a time reversal of assembly and time reversal switch for DNA?

In ZEO one must seriously consider the possibility of reverse translation, reverse transcription and reverse polymerization. The recombination of DNA strands, which is the least well-understood part of meiosis, might involve time reversal of the polymerization of the passive strand and also DNA repair might involve time reversal. Time reversal might allow the healing of genetic defects.

Time reversed processes might occur at least in DNA scale but it is an open question whether they occur in long time scales. As already found, matter-antimatter asymmetry and chiral selection pose strong constraints on the allowed time reversals: they can occur only for the conjugate DNA strand as catalyzed processes. The time reversal of translation is not possible but time reversal of transcription using the conjugate strand is.

1. Few natural scientists like the branch of philosophy called deconstructionism (in particular, ”anything goes” irritates any TOE builder) but it would seem that deconstruction is an excellent characterization of assembly and de-assembly as time reversals of each other.

Deconstruction would not be actually a new idea. Sustainable development means that nowadays wastes are treated systematically. Various mechanical and electric devices are de-constructed into their basic building bricks to be used again.

Why not the same in biology? For instance, could proteins be deconstructed to tRNA and mRNA, which in turn would be deconstructed to mRNA codon? It turns out that chiral selection prevents time reverse translation.

2. Deconstruction at the level of DNA would naturally involve time reversed DNA + dark DNA and very naturally the passive strand related by a conjugation to active strand would be now active. Deconstruction would be a construction in a reversed time direction. Could this give a reason why for the presence of the passive DNA strand?

One must clarify how the strands are related? What does time reversal do to the strands?

- (a) Since charge conjugation replacing protons with antiprotons does not occur, C must act trivially. $CPT = 1$ which is identity in quantum field theories but in TGD states that the states at the boundaries of CD are permuted - the corresponding fermionic vacua are analogous to Dirac sea and its conjugate. This implies that PT acts trivially and T acts as a reflection P changing the chiralities and direction of the strands.
 - (b) Time reversal would transform left-handed strand to right-handed *vice versa* and the 3' and 5' ends would be permuted. The effect would be a permutation of the strands geometrically. DNA strands would become their mirror images geometrically and for the 3' \rightarrow 5' orientation the order codons would be the same.
 - (c) The strands of DNA have opposite chiralities. Chiral selection can explain why only the second DNA strand is active: there are no enzymes catalyzing its transcription. In the time reversal the passive strand would become active and the time reversed DNA transcription would begin from 3' end so that the resulting mRNA would conjugate of the mRNA associated with the active strand. For standard time direction the process would look like conjugate mRNA sequence approaching the usually passive strand and decaying to the "loose" mRNA codons [Pitkänen 2020_b] (nucleotides in standard picture).
 - (d) If the processes proceed from 3' \rightarrow 5' direction determined by chemistry, the time reversed transcription would produce the same mRNA. In standard time direction mRNA consistent with conjugate DNA strand would attach to conjugate DNA strand and split to RNA codons (in TGD and to RNA nucleotides in standard picture).
3. How could one achieve the deconstruction of say mRNA as a time reversal at the level of DNA? Could there exist a simple time reversal switch in DNA reversing the electric field of DNA+dark DNA? Could there be an enzyme changing the position of this switch?

What could be this switch? In next section it will be proposed that switch would just move the part of the dark proton sequence associated with sticky end nucleotides to the opposite end of the DNA strand! There would be a proton current flowing along the ordinary DNA strand.

These switching currents could be the counterparts for the direct currents of Becker [Becker 1990_a, Becker 1990_b] and would change the direction of DNA's electric field! This mechanism would change the arrow of time and direction of the electric also at the level of the entire body as it falls in sleep or wakes up! Same applies to the electric field from the frontal lobes to hindbrain.

2.2 DNA transcription and replication and their time reversals

Could the time reversals of DNA replication and transcription occur? Is the depolymerization of the DNA strand equivalent to the time reversal or polymerization or are these separate processes? Does the time reversal of the replication make sense?

The basic constraint comes from the discrete symmetries. By matter-antimatter asymmetry charge conjugation is trivial - otherwise also antiprotons would define representation of the dark code. Since the generalization of quantum field theoretic identity $CPT = 1$ holds true one must have that a generalization of $PT = 1$ holds true. Time reversal would change the chirality of DNA strands.

Chirality selection for enzymes in turn poses a second powerful constraint meaning that time reversed processes can occur for the passive conjugate DNA strand only (having opposite chirality as compared to active DNA strand). The implication is that enzyme, which have a fixed chirality, can catalyze in standard time direction only processes for the active DNA strand but not for the passive strand. Enzymes can however catalyze time reversed processes for the conjugate strand. In particular, the degradation of active DNA strand cannot be equivalent with time reversal of polymerization since the latter cannot be catalyzed by enzymes.

Consider first the discrete symmetries in more detail.

1. The key constraints emerge from the ZEO based generalization of the $CPT = 1$ identity of quantum field theories generalized to ZEO. Here C is charge conjugation, P is reflection and T time reflection. In ZEO "1" is replaced by permutation of states at the opposite boundaries of CD defining the zero energy state and the replacement of Dirac vacuum with its conjugate. Call this permutation operation P_{ZEO} so that one has $CPT = P_{ZEO}$.
2. Since antiprotons are not involved in biology by matter-antimatter asymmetry, $C = 1$ is true and one obtains $PT = P_{ZEO}$. Therefore T must act as reflection and map DNA strand to its mirror image. Chirality is changed and the order of codons becomes opposite and 3' and 5' ends are permuted. The DNA strand looks like the original one as far as codons are considered but is its geometric mirror image

so it is not expected to be active - unless P permutes 3' and 5'. From Wikipedia [Wikipedia_g] one learns that this is not the case. Hence the conjugate strand would become active in the time reversal.

In particular, the time reversed catalyzed processes can use only the conjugate strand as a template since only in this case the enzymes satisfy the chirality constraint. In particular, this applies to polymerization and depolymerization, which are not time reversed process as was the first guess. Furthermore, the polymerization for conjugate strand is depolymerization in reversed time direction.

Matter-antimatter asymmetry and chiral selection therefore imply that catalyzed processes for the active DNA strands are in the standard time direction and for the passive DNA strands in the opposite time direction.

Some examples help to understand what would be involved.

1. Consider first the time reversal of the transcription. If the time reversal occurs it must attach mRNA strand to the time reversed conjugate strand and the time reversed transcription would mean splitting of mRNA to "loose" codons [Pitkänen 2020_b]: this process can be catalyzed by enzymes with standard chirality. If the conjugate of the gene coding for mRNA does not exist as a gene, this process is not possible. Therefore mRNA must allow also the ordinary depolymerization catalyzed by enzymes. Same is expected to apply to the depolymerization of DNA and proteins. Loose codons would be analogous to tRNAs.

This raises a question about how symmetric the spectrum of genes is. How often does the conjugate of gene exist? If there is strong symmetry breaking the reverse transcription rarely occurs.

2. An interesting challenge is to understand the details of DNA replication and its possible time reversal. What constraints does the chiral selection for enzymes pose? The replication of both strands is catalyzed by the same enzyme: DNA polymerase and the processes occur simultaneously. Since enzymes have single chirality only, this leaves only one possibility: the replication of the conjugate strand involves time reversal and is depolymerization in the reversed arrow of time.

Indeed, the replication of the conjugate strand occurs in a direction opposite to the ordinary ($3' \rightarrow 5'$). The replication of the conjugates strand would be the decay to codons but in reversed time direction. Note that the splitting of the DNA double strand to separate strands (unentangled quantum systems) is necessary to change the arrow of time only for the conjugate strand.

2.3 Meiosis and time reversal

Meiosis is an especially interesting application since the reshuffling of DNA strands in meiosis is not well-understood in biology-as-nothing-but-chemistry approach. The crucial

step is the shuffling of the corresponding pieces of homologous DNA strands. Could the reshuffling involve de-assembly regarded as a time reversal of the assembly followed by re-assembly meaning a return to the original arrow of time: this would be completely analogous to what mechanic does when repairing a machine. Also the DNA repair could rely on this mechanism.

1. The first observation made already earlier is that the formation of several reconnections between - say - active DNA strand involving touching at several points with subsequent reconnection at the level of magnetic flux tubes would give an elegant description for the reconnection at the level of say active strands. Here magnetic flux tubes would demonstrate their explanatory power.

The problem is that if this occurs for pairs of both active and passive strands, there is no guarantee that the reconnection patterns determining the re-shuffling are consistent. How can one guarantee this?

2. Here time reversal of polymerization for the passive DNA strand comes in rescue. Two BSFRs changing the arrow of time would take place.
 - (a) The arrow of time changes for both strands of DNA. At the de-assembly step the passive strand decays to codons. This is just time reversal for polymerization and by the chirality selection for enzymes only the passive strand can de-assemble in this manner. This happens for the conjugate strands of both double DNA strands involved.
 - (b) At the shuffling step the two formerly active time reversed DNA strands pair with each other and the repeated reconnections about as a sequence of SSFRs inducing shuffling of the pieces of DNA. This process cannot be catalyzed by enzymes since the required chirality would be wrong. Since the outcome is non-deterministic the situation must be quantum critical in the sense that the classical time evolutions defining the zero energy state are initial value sensitive and state function reduction selects superposition of evolutions corresponding to the same outcome.
 - (c) At the re-assembly step the arrow of time changes back to the original for the resulting shuffled active DNA strands replicate.

Whether the translation of mRNA to proteins could have a time reversal was asked in the earlier article [Pitkänen 2020_b]? This does not seem to be possible. Due to the chiral selection proteins do not have double strand structure with strands possessing opposite chiralities. Also mRNA has only one chirality. Therefore the time reversal of translation proceeding from mirror proteins and mirror tRNA to mirror mRNA is not possible.

3 Could the sticky ends make DNA double strand a conscious ferro-electret?

The basic motivation for this section could be Becker's finding [Becker 1990_a, Becker 1990_b]; its direction determines whether the system is awake or asleep. In ZEO [Pitkänen 2020_a] these states could correspond to opposite arrows of time at some level of the fractal hierarchy of the layers of MB labelled by the values of h_{eff} . The arrow of time would change in BSFR. The sign of the longitudinal electric field correlates with the arrow of time on basic of the basic properties of electromagnetic field tensor so that BSFR should change the direction of electric field: this suggests some kind of switch changing the arrow of time and in standard ontology turning consciousness on/off.

Could the same be true for DNA + dark DNA system as well? In the sequel the idea that sticky ends make the DNA double strand + its dark counterpart with $h_{eff} > h$ a ferro-electret carrying longitudinal electric field is considered. The longitudinal electric field is non-vanishing also in standard framework without dark DNA if the lengths at the ends of the DNA double strand are different. This field would be analogous to the electric field along the body axis.

3.1 Different ends of DNA double strand

There is a variety of different ends of DNA double strand and of telomere.

1. Blunt ends contain two paired bases so that they do not define a full codon.



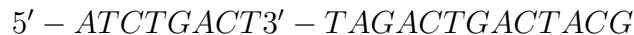
Straight cut by exonuclease enzyme produce blunt ends.

2. Overhangs are short, mimally just one nucleotide A in 3' end: one could have for instance following configuration



Overhangs are most often palindromic.

3. An example of longer sticky end is following:



The length of the unpaired portion of sticky end can be hundreds of nucleotides.

4. Frayed ends correspond to sequence of basic pairs breaking the A-T, C-G pairing rules.



3.2 Empirical evidence for the ferroelectret property of DNA

To the best of our knowledge, there is no reported evidence for longitudinal static electric fields in DNA in an extensive Web search. This might be simply because of inability to measure them in past. Indeed, a model for DNA nucleotides A,T,C,G as ferroelectrets based solely on standard chemistry is discussed [Zhejiang 2005] and would imply that also DNA can be ferroelectret. This could in a special case give rise to a longitudinal electric field, and if there is an electric field in the absence of external electric field (spontaneous ferroelectricity), it could be also in the direction of DNA strand.

The reported existence of electric currents along DNA perhaps analogous to Becker's DC currents is one indirect evidence for the longitudinal electric field. A very interesting test would be so called DNA crystals [Seeman 2007, Heckel and Famulok 2008, Mallonee 2015] in electric field, heated, or put under mechanical stress.

DNA is analogous like cell interior being negatively charged with one negative charge per nucleotide assignable to the phosphate. The stability of DNA against Coulomb force is however not well-understood and TGD would solve the problem with a pairing of DNA strand with a parallel helical flux tube carrying 3 dark protons per codon with dark proton triplet realizing genetic codon. Ordinary chemical codons would be a secondary representation of the code. Could this make possible ferroelectret property of DNA?

3.3 Could the sticky ends of the telomeres give rise to a longitudinal electric field along DNA?

In the standard picture about DNA different negative charges at the sticky ends could give a longitudinal electric field proportional to the difference of the charges. DNA double strand would however have a net charge now. Second possibility is that the nucleotides behave as dipoles even in the absence of the external electric field. If these dipoles are forced to be parallel to DNA by an external electric field they give rise to a longitudinal electric field.

TGD based view is that DNA is paired with dark analog of DNA. This view leads to the suggestion that sticky ends/overhangs give rise to positive or negative charges at the end of DNA and that opposites at the ends of DNA generate strong longitudinal electric field along DNA. For DNA with blunt ends there would be no electric field.

What would be needed for chromosome as dipole like entity is that the ends of the chromosome carrying the telomeres have charges of opposite sign: in the simplest case they would have the same magnitude so that one would have a dipole.

3.3.1 Could telomeres be analogous to microtubules?

Microtubules are highly dynamical having a varying length. They also have a longitudinal electric field [Trkal, Pkorny and Jelinek 1998, Trkal et al 1997]. Likewise, the the ends of chromosomes are dynamical and their length is changing and controlled by the telomerase

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enzyme [Audry et al 2018, Sun et al 2013]. Could telomeres or entire chromosomes be analogous to microtubules? Could chromosomes [Wikipedia_a] carry longitudinal electric fields? That would not be surprising since living matters are populated by ferroelectrets [Wikipedia_e].

Remark: The option that only telomeres could carry these fields would require that the joint between the coding portion of DNA and telomere is charged. This does not look natural.

Due to the properties of the electric field under time reversal, the direction of the bio-electric field would in TGD Universe correlate with the arrow of time [Pitkänen 2020_a] changing in "big" (ordinary) state function reductions (BSFRs) meaning "death" or "falling asleep" and re-incarnation with an opposite arrow of time. In particular, sleep could correspond to conscious experience but with a different arrow of time at some level of the hierarchy of layers of MB) [Pitkänen 2018_b] serving as master controlling the biological body (BB).

Remark: The hierarchy of Planck constants $h_{eff} = nh_0$ labelling phases of ordinary matter behaving like dark matter predicts [Pitkänen 2017_a, Pitkänen 2018_b] macroscopic quantum coherence explaining the coherence of biomatter. This allow BSFRs in arbitrarily long length and time scales, for instance, the scales of chromosomes.

The first guess motivated by the findings of Becker about bio-electric fields [Becker 1990_a, Becker 1990_b] is that when the telomere shortens, the electric field associated with DNA weakens, and eventually the organism dies [Writh, Chai and Shay 2005]. Telomere length is controlled by telomerase enzyme and for stem cells, germ cells and cancer cells the shortening does not occur [Hyiama and Hyiama 2007].

Telomeres are dynamical and could somehow provide DNA with a longitudinal electric field closely related to this dynamics. The strength of the electric field associated with the DNA double strand could correlate with the properties of telomeres and in particular the lengths of their negatively charged sticky ends at the ends of the chromosome.

3.3.2 The TGD based model for DNA as ferroelectret

Although most of the telomere has a normal base-pairing, there is an additional unpaired nucleotide sequence - overhang - associated with either strand. In the minimal case it is just one nucleotide A. What could this mean in TGD framework: could it give the desired constant electric field along DNA strand. Is its strength proportional to the length of the overhang determined by the number of its nucleotides? There would be 1 negative charge per nucleotide.

1. Suppose that both strands are accompanied by dark DNA strands parallel to them and having opposite charge neutralizing the DNA in the scale of this pairing. Dark codon would be identified as a 3-proton unit. Dark RNA, tRNA and amino-acids are predicted. Vertebrate genetic code is predicted correctly in the sense that the

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number of DNA codons corresponding to given dark amino-acid is the same as for vertebrate genetic code [Pitkänen 2018_a, Pitkänen 2019_a].

2. What could be the counterpart of the sticky end for dark DNA sequence? Suppose that the dark DNA strands be equally long so that there would be no symmetry breaking. This leaves two natural options for a given sticky end.

- (a) Both dark DNA strands have portions associated with the sticky end. Since the sticky end/overhang would be neutralized, this would give for the end of the double strand a positive charge $Q = ne$, n the number of nucleotides in the sticky end.
- (b) Both dark DNA strand portions are missing at the sticky end. Now the charge would be negative and equal to the charge $Q = -ne$ of the sticky end.

3. The magnitude of the electric field along DNA flux tube created by a single sticky end would be

$$E = \frac{Q}{S} = \frac{en}{S} ,$$

where S is the thickness of the system DNA + dark DNA. The fields of the sticky ends sum up and there would be a net electric field along DNA double strand +dark DNA given by

$$E = \frac{Q_1 - Q_2}{S} = \frac{e(n_1 - n_2)}{S} .$$

One can consider two options.

Option I: There is dark DNA present (TGD option) and the situation is a) at the first end of the chromosome and b) at the opposite end. One obtains opposite signs of charges $Q_1 = n_1e$ and $Q_2 = -n_2e$ and electric field is $E = (n_1 + n_2)e/S$.

Option II: There is no dark DNA (standard physics option). The charges at the sticky ends are negative and one has $E = e(n_1 - n_2)/S$.

4. The video about telomeres [Sandhu and Li 2011] suggests that the sticky ends are associated with different DNA strands and are of the same length. For the standard physics option (no dark DNA) charges at the sticky ends have the same sign and one has $E = e(n_1 - n_2)/S$. The field vanishes for Option II and equals to $E = 2n/S$ for Option I.

This field would be quite strong. The electric fields at opposite ends of the chromosome sum up and cancel each other along DNA if the charges are of the same sign : there is however positive interaction energy causing a repulsive force. For the TGD option the Coulomb energy is negative. For the standard physics option it would be positive and would not favor the stability of DNA.

3.3.3 Quantitative estimates

In the sequel some simple quantitative estimates are performed.

1. *Minimization of electrostatic energy taking into account only the nearest neighbor interactions*

The system must minimize its electrostatic energy to be stable. Assume that the charges of the overhangs are opposite: $n_1 = -n_2 = n$. For the more general situation with $n_1 \neq n_2$. For the same sign for n_1 and n_2 there would be a repulsion between the ends of DNA.

1. In this case overhangs would give a negative contribution to the electrostatic energy of the system.

$$E_{ends} = -\frac{n^2 e^2 L}{S} ,$$

where L is the length of DNA double strand without overhangs and S is its transversal area. Otherwise the contribution is positive.

2. The negative electrostatic energies between dark strand and ordinary strand with opposite charges. There are two pairs of this kind. In the first approximation one has

$$E_{OD} = -2N \frac{e^2}{R_{OD}} .$$

N is the total number of nucleotides in DNA without overhangs and R_{OD} is the distance between dark and ordinary DNA strands. One has $N = (dn/dl)L$, where dn/dl is the number of codons per unit length. One has approximately $dn/dl = 10$ nucleotides per nanometer.

This gives

$$E_{OD} = -2 \frac{(dn/dl)e^2 L}{R_{OD}} .$$

The ratio of the two negative contributions tending to stabilize the system is

$$r = \frac{E_{OD}}{E_{ends}} = 2 \frac{(dn/dl)S}{R_{OD}} \simeq \frac{20S}{nm \times R_{OD}} .$$

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3. There are positive electrostatic interaction energies between dark strands with distance $R = R_{DD}$ and ordinary strands with distance $R = R_{OO}$. The energy is given by

$$E = \frac{Ne^2}{R} = \frac{(dn/dl)e^2L}{R} .$$

The total contribution to the electrostatic energy is positive and given by

$$E_{OO} + E_{DD} = (dn/dl)e^2L \times \left(\frac{1}{R_{OO}} + \frac{1}{R_{DD}} \right) .$$

The total electrostatic energy in this approximation is

$$E = e^2L \left[-\frac{n^2}{S} - 2(dn/dl) \left(\frac{1}{R_{OD}} - \frac{1}{R_{OO}} - \frac{1}{R_{DD}} \right) \right] .$$

4. The generalized electrostatic force in the longitudinal direction is given by

$$F = -\frac{dE}{dL} = -e^2 \left[-\frac{n^2}{S} - 2(dn/dl) \left(\frac{1}{R_{OD}} - \frac{1}{R_{OO}} - \frac{1}{R_{DD}} \right) \right] .$$

For $n > n_{min}$ DNA tends to get longer and for $n < n_{min}$ it tends to get shorter.

5. In equilibrium this force must vanish. $F = 0$ condition fixes the number n of nucleotides in the sticky end:

$$n^2 = n_0^2 = (dn/dl) \times S \left[-\frac{2}{R_{OD}} + \frac{1}{R_{OO}} + \frac{1}{R_{DD}} \right] ,$$

This gives

$$n = n_{min} = \sqrt{(dn/dl) \frac{S}{R_{DD}}} \times \sqrt{-2 \frac{R_{DD}}{R_{OD}} + \frac{R_{DD}}{R_{OO}} + 1} = \sqrt{\frac{10S}{R_{DD}nm}} \sqrt{-2 \frac{R_{DD}}{R_{OD}} + \frac{R_{DD}}{R_{OO}} + 1} .$$

Note that the condition $n_{min} > 0$ requires that without the overhangs at the end the configuration would be unstable.

$$2 \frac{R_{DD}}{R_{OD}} \geq \frac{R_{DD}}{R_{OO}} + 1 .$$

must hold true. Since the right-hand side is larger than unity one must have $2R_{DD} > R_{OO}$. As a special case one could have a maximally symmetric DODO

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type configuration with $R_{OO} = R_{DD} = R_{OD}$ for which the above inequality becomes equality and one has $n = 0$. $n = 1$ is realized rather generally and is maximally near to this situation

6. n would not depend on the length L of the chromosome in the approximation taking into account only the nearest neighbor interactions between various DNA codons. Taking them into account implies that the electrostatic energy is a nonlinear function of L and n_{min} is predicted to depend on L - probably the dependence is weak suggesting that the dependence of $L = L(coding) + L(telomere)$ - or actually the telomere length $L(telomere)$ - on n_{min} is strong so that it would be an ideal control variable.
7. The increase of the length n of the overhang creates a force increasing the length of DNA and its reduction does the opposite. One can say the situation is critical and that $n = n_{min}$ stabilizes the situation. The reduction of the length of overhang below critical value would have disastrous effects.

This model is certainly not the only one that one can imagine and involves drastic approximations since only the nearest neighbour Coulomb interactions has been taken into account. Also the sticky ends of the chromosome could have different lengths and thus charges so that the chromosome would have a net charge and the stable length for DNA would depend on this charge.

Also the distances between various DNA strands serve as parameters and the stable length depends on these parameters: these parameters could depend on chemical parameters like pH and thermo-dynamical parameters. The length of the sticky end is expected to vary also during the life span of the chromosome and also depend on how many DNA replications preceded the generation of the chromosome. The length of the sticky end has spectrum and implies a spectrum for the telomere length since the length $L(coding)$ of the coding part of the chromosome cannot be changed. In the linear approximation all lengths $L = L(coding) + L(telomere)$ are allowed and if the corrections are small, $L(telomere)$ is very sensitive to $L(stickyend)$.

The length of the sticky end rather than the length of the telomere would be the primary controller. The quite high strength of the longitudinal electric field is a surprise. An interesting prediction is that prokaryotes with circular DNA strands would have no wake-up-sleep cycle like eukaryotes. Viruses however have both circular and open strands.

2. Minimization of the electrostatic energy taking into account interaction between non-nearest neighbors

What kind of corrections the inclusion of the Coulomb interactions between charges, which are not nearest neighbors, could have?

1. Nearest neighbors have been identified as neighbors in transversal direction and it has been assumed that only DNA-DNA and DDNA-DDNA, and DNA-DDNA

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interactions matter. A better approximation would take into account the repulsive nearest-neighbor interactions between phosphates and between dark protons along dark DNA. Same applies to DNA-DDNA interactions.

All these terms give a contribution proportional to L and mean only a scaling of the parameter n_0 , whose order of magnitude remains the same and by the presence of the longitudinal dipole electric field can be positive.

2. Consider the contribution of the interactions of given DNA codon and DDNA codon with the non-nearest neighbors along DNA and dark DNA. These interactions can be regarded as dipole and higher multipole interactions since the total charges of the codon pair DNA + DDNA vanish. In the lowest order approximation dipole-dipole interactions depending on the distance r between dipoles like $1/r^3$.
3. Simple dimensional arguments give the general form of the dipole contributions. By dimensional considerations alone, the sum over dipole interaction energies for a given codon or nucleotide gives a contribution proportional to $1/L^2$. Summing over these contributions gives a total contribution proportional to $1/L$.

The dipole contribution is proportional to $(dn/dl)^2$, to the square of the dipole moments of a given nucleotide (codon). Since dipole moments are of the order eR , R the transversal scale of DNA+DDNA system, individual dipole-dipole interaction energy is proportional to e^2S

Therefore the Coulomb interaction energy would be of the general form

$$E = \frac{e^2L}{S}[-n^2 + n_0^2] + ke^2(dn/dl)^2\frac{S}{L} .$$

where k is a numerical factor determined by the details of the model. Note that dark protons forming a dark variant of ordinary nucleus are expected to have also counterparts of strong interactions expected to be short ranged.

4. The minimization of energy would give

$$F = -\frac{dE}{DL} = \frac{e^2L}{S}[-n^2 + n_0^2] + ke^2(dn/dl)^2\frac{S}{L} = 0 .$$

This gives for $L(n)$

$$L(n) = \frac{dn}{dl}S\sqrt{\frac{k}{-n^2 + n_0^2}} .$$

The condition that the argument of square root is non-negative, implies that one must have either $(k > 0, n < n_0)$ or $(k < 0, n > n_0)$. $n < n_0$ option seems to be the physical one.

5. $n < n_0$ requires $k > 0$ so that the dipole interaction energy is positive. For $n \rightarrow 0$ L approaches to

$$L(0) = \frac{dn}{dl} S \sqrt{\frac{k}{n_0^2}} .$$

$L(0)$ could correspond to the length for the coding part of DNA (no telomere is allowed). At the limit $n \rightarrow \infty$ $L(n)$ approaches infinite value and the length of the telomere becomes extremely sensitive to the value of n and n becomes an ideal control variable.

For $n > n_0$ one must have $k < 0$ meaning that the contribution of the dipole-dipole interactions to the total energy is negative. The stable DNA length shortens roughly like $L \propto 1/n$ as n increases: this does not conform with the intuitive picture.

3.3.4 Relation to TGD inspired theory of consciousness

Two remarks from the point of view of TGD inspired theory of consciousness based on ZEO are in order.

1. The proposal motivated by the properties of electromagnetic field tensor under time reflectin T is that the direction of electric field flux should correlate with the arrow of time. One would expect that the change of the arrow of time requires the change of the direction of the electric field. Somehow the length of dark DNA should be reduced at the first end and increased at the opposite end.

Could the dark protons be added to or removed from the flux tube defining dark DNA to achieve this. Pollack effect [Zhao, Pollack, Figueroa 2009] is in TGD framework indeed explained in terms of the transfer of ordinary protons to dark protons (with $h_{eff} = nh_0 > h$) at the dark magnetic flux tubes [Pitkänen 2014_d] and has become basic element of the TGD inspired quantum biology.

The roles of DNA strands are expected to change in time reversal so that the active strand (the transcribed one) would become passive and *vice versa*. The gene expression would come however its time reversal: mRNA would be un-transcribed to mRNA codons by the formerly passive strand.

2. If one could change the roles of active and passive strands by changing the arrow of time - that is the direction of the longitudinal electric field of DNA - by changing the numbers of dark protons at the ends of DNA, one could have a dramatic demonstration for the key idea. An external electric field with direction opposite to that of DNA might allow achieving this. This would be like changing the direction of spontaneous magnetization by using an external magnetic field.

3.4 Tests for the TGD based model of DNA as ferroelectret

The standard physics view is that the possible ferroelectricity for DNA is due to the instantaneous polarization of codons A,T,C,G in external field which is proportional to electric field E if the polarization vanishes for $E = 0$. Ferroelectricity is analogous to spontaneous magnetism that there is electric field also for $E = 0$: this requires permanent electric dipole moments generated by small external field and left when the field is taken to zero.

In [Yam et al 2018] a model for the polarizability of nucleotides A,T,C, G is developed based on standard physics so that the external electric field would generate dipole moment for given nucleotide. What one hopes is to have a model producing ferro-electric behavior. The model calculations give ferroelectric behavior and a square shaped hysteresis curve. In case of entire DNA each nucleotide would behave independently in inhomogeneous electric field with varying direction.

Also in [Zhejiang 2005] the dipole moments are estimated for both bases and nucleotides, and the estimated dipole moments are in the range of 2-6 Debyes ($D = .02$ enm) that is $.04 - .12$ enm. TGD estimate for the electric field is about ne/S , $S = \pi R^2$ the effective area of the flux tube assignable to DNA + dark DNA.

The first thing to notice is that the flux would be along entire DNA, not only the telomere and the overhangs portions carry the charges creating the electric field along DNA. Electric flux flows along DNA. Telomere would be a kind of buffer against the evil world. Overhang/sticky ends could play a key role in control of the arrow of time for DNA. Similar mechanism would be at work at the level of entire body changing the direction of endogenous electric field and leading to wake-up to sleep or *vice versa* [Becker 1990_a, Becker 1990_b].

Suppose that the charges at the opposite ends of DNA are of opposite sign. An unnecessary strong assumption is that they are of the same magnitude. The dipole moment would be roughly given by the difference $Q_1 - Q_2$ of the charges multiplied by the distance L between ends of the chromosome along the DNA strand. Note that the channeling of electric flux along DNA would be rely on TGD view about space allowing monopole flux tubes whose deformations carry also electric field.

The static electric field would be realized as a conserved electric flux flux along the entire DNA, not only telomere. The order of magnitude is 10 GV/m for $R = 1$ nm so that it would be rather strong. The strength of electric field is proportional to $1/R^2$ and R is expected to vary in the range 1 – 10 nm. Note that $L(151) = 10$ nm corresponds to the p-adic length scaled the thickness of the DNA coil and chromosome thickness.

The effective dipole moment per nucleotide would be $p \simeq ned \simeq n \times .3$ enm and quantized as multiples of n . The estimate is at most by a factor 2.2 – 7.5 larger than the estimates from the atomic contributions and would allow to select between the standard model and TGD based model.

3.4.1 Nanoscopic implications

What could be possible experimental consequences of the proposed electric field? Consider first the situation at the level of single DNA double strand.

1. The accelerated motion of a test charge along DNA could serve as a test for this option. One can consider both quantum motion without dissipation - perhaps along the dark DNA - and Ohmic current along the ordinary DNA. They would run also in absence of external electric field unlike ordinary Ohmic currents.

These currents could be nanoscopic analogs of the DC currents observed by Becker in body scale and brain scale. If they are steady currents the current is conserved and must return so that a closed current loop is formed. The currents could be also pulselike taking surplus dark protons between ends of the chromosomes and changing their roles. This would be quantum event associated with BSFR and could mean time reversal.

Electronic (not protonic) currents along DNA [Ratner and Decker 2001] have been observed for single DNA strands in an external electric and it is found that the conductivity is surprisingly high. In the recent case conduction double strand property and sticky ends would be essential.

2. How could the current return in steady situation? This question must be answered also for Becker's current. Does the current flow as ohmic current along ordinary DNA and return back along the dark DNA as non-dissipative current? The proton current along DNA along electric field to negatively charged and dark protons would be accelerating: the quantum description would correspond to a particle in linear potential, which is standard quantum mechanical problem.

The larger the charge (the length of the sticky end), the stronger the current. Its magnitude would be quantized being proportional to the length and charge ne of the sticky end. The variation of sticky end length would vary the strength of the current.

There is evidence for proton AC current conduction in the DNA double strand-imidazole composite material under anhydrous conditions (no water) in the frequency range 4 Hz - 1 MHz [Yamada and Goto 2012]. If the mechanism is the proposed one - probably not - the oscillatory current could correspond to occurrence of BSFRs changing the arrow of time with 2 BSFRs *per* each period of $T = 1/f$. This would predict the current to be $I = 2nef$, where $\pm ne$ are the charges at the ends of the double DNA strand.

3.4.2 How to test whether DNA double strand is ferroelectret?

1. The measurement of the possible longitudinal electric field of DNA and its correlation with the length of the telomer or of the sticky end would be an interesting

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experimental project. DNA exonuclease restriction enzyme allowing to cut pieces from the end of either DNA strand could allow creation of desired length of unpaired portion of DNA. Also blunt ends could be created and the prediction is that there is no electric field in this case.

2. The telomere or the entire DNA would be like a dipole and would interact with external electric fields. One should be able to prepare a DNA sample as an electret so that DNAs would have the same dipole direction and this structure could be put in an electric field allowing to measure the dipole moment of DNA as a macroscopic motion in the field.

The external electric field would give rise to a torque acting on the entire DNA double strand. If nucleotides behave as independent dipoles as the standard physics based model suggests, this would not be the case and the dipole moments of the nucleotides would only turn in the direction of the external field.

3. One could also study whether and how the possible DNA dipole moment making sense for short enough DNA double strands is affected by the telomerase affecting the length of telomere. The first guess would be that is the length of the sticky end which is affected and that the length of the telomere correlates with this by stability conditions. Pyroelectricity [Wikipedia_e] and piezoelectricity [Wikipedia_f] and the use of external electric field produce ferroelectrets from various biological tissues [Athensteadt 1974]. These methods applied to DNA crystals [Seeman 2007, Heckel and Famulok 2008] could allow to test the hypothesis.

The measurement of the possible longitudinal electric field of chromosome or DNA double strand and its correlation with its length could serve as a futuristic bioelectric marker: this could be an experimental project. Currently, the measurement of telomere length by quantitative PCR is quite common and for a summary of critical factors and recommendations for assay design, interested readers may see [Este, Drury and Smith 2019]. Also, a full description and protocol for examination of the telomere G-overhang structure in different plant, human and vertebrate models are available [Bhusari et al 2010, Trantirek et al 2013, Fajkus et al 2000, Sandhu and Li 2011].

3.4.3 Could pyroelectricity, piezoelectricity, or the behavior in external electric fields be used to demonstrate that DNA has a longitudinal internal electric field

One can consider also the consequences at condensed matter level. Athensteadt has found [Athensteadt 1974] that it is possible to make various tissues of vertebrates piezoelectric or pyroelectric.

Pyroelectric materials [Wikipedia_e] are crystals in which the change of the temperature involving thermal energy flow induces a macroscopic electric polarization and therefore

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electric field making the material ferroelectric. In piezo-electric materials [Wikipedia_f] mechanical stress induces a generation of polarization and macroscopic electric field. Also an external electric field can induce polarization producing a ferroelectret.

One can visualize the situation using a triangle having kinetic, electric, and thermal energies as corners. For piezoelectric materials the motion occurs along the edge connecting electric and mechanical energy. For pyroelectric materials the motion occurs along the edge connecting electric and thermal energy.

The proposal is that DNA double strand + dark DNA strand carries internal electric field is 1-D ferroelectric aperiodic crystal due to its inherent polarization. One cannot exclude the possibility that also single DNA strand + dark strand has this property. DNA should be *in vivo* state. DNA crystals [Seeman 2007, Heckel and Famulok 2008] might allow to test the phenomenon. For instance, it is known that DNA suspended in liquid which is evaporated forms crystal [Mallonee 2015] Could DNA crystals become ferroelectrets by heating or cooling or by applying a mechanical stress or an external electric field?

If this would occur, the interpretation would be that DNA strands become parallel and have parallel electric fields giving rise to ferroelectricity. In the positive case, one could test the hypothesis by using DNA preparations with different values of n for the number of overhang nucleotides: electric field in the ideal situation would be proportional to n if the area density of the parallel DNA strands is the same.

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