

Coherence Domains in Living Systems

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Abstract

The recently “pictured” pair of Nano domains (NDs) interacting coherently in time was used here to further delineate ND-behavior and develop the structure of coherence domains of increasing size. This extension started with two pairs, then four, later with many more which eventually produced a “solid” sheath (containing coherent squares or rectangles within each other). These solid sheaths are stacked atop of each other forming a solid multi-layered “raft-like structure” called Coherent Domain (CD) (ranging in size from 1 μm to several μm). It is our proposal that these CDs would then be fitting into specific cavities within organisms where their shape may need to adjust to the environment. Very little is known about the latter and how everything interacts in a living system. Various possibilities including experimental approaches are discussed.

Keywords: Nano domains; Micro-cavities; Micro-chambers

Introduction

Coherence is a concept widely used in the science and technology of lasers [1]; it was later also found to exist in biology [2]. Coherence defines groups of electromagnetic waves (such as light) where all waves coincide in phase and time. Lasers have one perfect and one leaky reflector permitting waves to escape. On the other hand, in biology the coherence domains (CDs) have two perfect reflectors thus keeping the energy from escaping over long periods of time. Subsequently, the lifetime of coherence in lasers is just a few ns, while in CDs it is a few giga-seconds (Gs) or more! This difference has a vast implication for coherence domains in biochemistry.

Czerlinski and Ypma [3] recently described the functioning of CDs in a simple enzyme reaction. They also have described how a pair of special polymers of water molecules (Nano domains) in a coherence domain oscillate in time between an excited “singlet” state and (an electromagnetic) wave state. This takes place in the time range of femtoseconds (fs), far below the onset of chemical thermodynamics (circa 150 fs). This oscillation actually protects the excited state from decaying by thermal loss to the environment.

In this publication, we extend the oscillating process to more than one pair of nanodomains in coherence, to just two pairs, initially. Later, we will also look at the implications of some basic laws of physics, similar to the one introduced in the cited paper. This equation correlates the wave length present in the wave state to the distance of the two nanodomains involved.

A recent publication by Del Giudice et al. [4] will also be discussed, as it relates to the modulation of CDs in living systems. There we have to distinguish between “free” CDs and their physiological compartments that contain them.

The question before us (and handled in the Discussion) is: How are CDs designed, maintained and modulated within these compartments? Appendix 1 is added to review past 2D-structures in electrometric.

Methods

In discussing their Figure 1, Czerlinski and Ypma [3] introduced the relationship

$$a = m \lambda / 2 \quad (1)$$

with a = distance between two nanodomains in an interacting pair, λ = the wave length of the electromagnetic radiation involved (using 200 nm, the lowest one of the range), m = whole number >0 (mostly $m = 1$). We need to analyze λ from 200 nm and 800 nm and $m = 1$ or larger.

The velocity of electromagnetic radiation in the vacuum is related to the wave length by

$$c = \lambda \nu \quad (2)$$

With c = velocity of electromagnetic radiation in vacuum (a fixed value known to high precision, but generally rounded to 3×10^8 m/s) and ν = frequency of the electromagnetic radiation in s^{-1} . The frequency is then directly related to energy of a photon (its quantum energy) by

$$E = h \nu \quad (3)$$

Where h is Planck’s constant. The units of h then depend upon the units of energy used (such as J for Joules). The first law of thermodynamics then locks in the value of ν .

As at least about 1000 nanodomains cooperate to form a CD [3], the size of the latter is in the range of μm . CDs may be free floating in living systems or bound in structures which may then be labeled cavities or chambers. Are there special conditions imposed by CDs on the size and shape of these cavities/chambers or vice versa?

Del Giudice et al. report the average duration of the excited state as 10% and that of the ground state as 90% in steady state. They define the size of a coherence domain by the wavelength of the electromagnetic radiation arriving at the size of 0.1 μm . They also point to the influence of thermal noise producing a coherent fraction and a non-coherent one with their ratio constant. In contrast we feel that influence of thermal

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Received October 20, 2014; **Accepted** January 22, 2015; **Published** February 02, 2015

Citation: Czerlinski G, Ryba R (2015) Coherence Domains in Living Systems. Fluid Mech Open Acc 2: 110. doi: [10.4172/2090-8369.1000110](https://doi.org/10.4172/2090-8369.1000110)

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noise is prevented by the switching of excited state and wave state taking place within less than 100 fs. This fast switching also provides for the long life time of the excited state in a CD.

Earlier Del Guidice et al. [5] found another coherence involving the molecular rotational levels. The coherence distance “a” is then 500 μm and the electric polarization depends upon the presence of an external electric field. Preparata [6] describes a third kind of coherence (not discussed here).

Results and Discussion

Results are those elaborated on in the references cited and here further illustrated to enhance understanding and to facilitate the discussion. Figure 1 shows the mechanism of Nano domain creation (early steps in [7]), explicitly showing the three types of frequencies involved. The minimum number of water molecules participating is 8. The singlet excited state at the end is shown as linear.

Figure 1 describes about the mechanism of Nano domain production. Here, we start with nearly statistically distributed water molecules, represented by squares with rounded corners. Vibrational frequencies are denoted by the solid line at the top, frequencies of rotational extent of degeneracy are represented by a densely spaced sigmoidal wave; frequencies of translational extent of degeneracy by single sine wave. In the perfect lineup, all waves contribute to braking (in bold), thus leading to the complete flattening of the wave’s expression. The energy is essentially at absolute zero – for an infinitesimal period. See the text for additional information.

Figure 2 shows that the linear isomer at the bottom right of Figure 1 is in a rapid equilibrium with a circular isomer. The circular isomer is magnetizable and lines up in the geomagnetic field, as its response to magnetic fields is very high: For the first 100 fs after creation of the excited state (S1) the electron is in superconducting mode. Superconductivity converts the polymer into an excellent reflector which allows two of them to operate in a laser cavity without losing energy (as commercial lasers do).

Figure 2 describes about Ultra-fast energy switching. A linear isomer is shown in the upper 1/3, a circular isomer below. Their relative concentration is controlled by electric and magnetic fields (denoted by

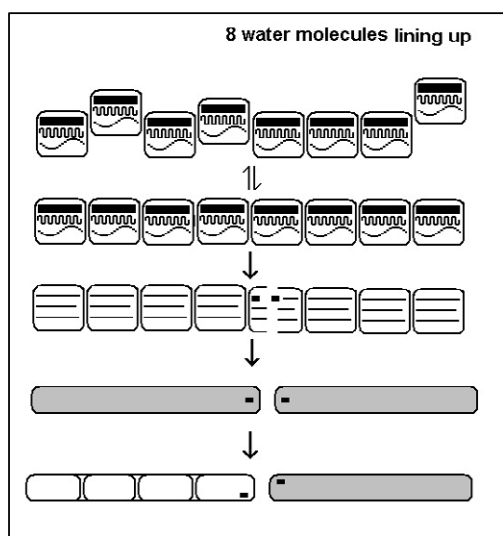


Figure 1: Mechanism of Nano domain production.

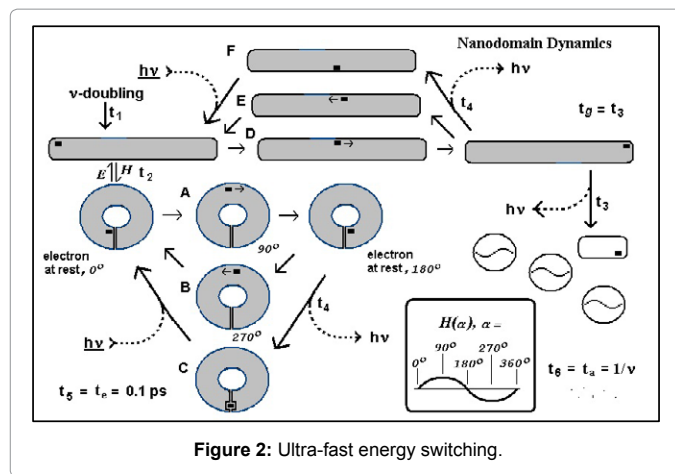


Figure 2: Ultra-fast energy switching.

double-arrows on the left connecting the two isomers, time constant t_2). The linear isomer is produced from two triplets (formation constant t_1) with the energy-donating triplet decomposing to monomers (with one water molecule as radical). One of the linear isomers is shown to decompose with t_3 .

For both linear and circular isomer the singlet excited state is indicated by the bound electron (heavy dot) “up”. Three “locations” of the electron are shown: Resting (on the left side), fast moving (in the middle, path A and D respectively) and then again resting (on the right). The electron then moves back (path B for circular isomer compared path E for the linear one). Two more paths involving C and F show photon capture on the left and photon release on the right (with time constant t_4 which denotes the transition to the wave state). All molecules in a coherence domain show this behavior with orientation and phase precisely in synchrony. Around the reaction circles symbol “hv” denotes the wave state which is started and stopped by all cooperating Nano domains at precisely the same moment (they are in coherence). Constant t_5 (bottom left) defines the upper limit of the switching process and is currently estimated at 100 fs, while t_6 is the time (in s) for one full cycle (α from 0 to 360°). The section in the lower right is discussed in the text.

For both isomers Figure 2 shows steps in the full life of the excited state which in coherence is always less than 100 fs (and so is the intervening wave state). The excited state starts with the absorption of hv on the left of Figure 2. After $m/2$ cycles the excited state converts to a departing hv as shown on the right (as t_3 for $m = 1, 3, 5 \dots$, limited by v). The linear isomer is unstable and loses its energy incoherently at t_4 (with $t_4 \gg t_3$). Time constant t_5 (estimated near 100 fs) defines the upper limit of quantum physics. The expansion in time of a quantum of energy is given by $t_6 = 1/v$. This t_6 covers the full 360° cycle of movement of the electron in its nanodomain (A and B as well as D and E show the electron at its point of maximum velocity). The square box with rounded corners in the lower right of Figure 2 shows the magnetic field vector as a function of α , the angle of rotation over a full circle. In the circular isomer a membrane (at the bottom of the circle) prevents the electron from moving over the full circle. If α' denotes the real movement of the electron and α'_{max} its maximum movement, then the computational α is given by $\alpha = 360^\circ \alpha' / \alpha'_{max}$ with $360^\circ > \alpha'_{max} > \alpha'$.

The energies produced by coherent action of 8 (to possibly 16) water molecules (as shown in Figure 1) cover a spectral range of

ultraviolet and visible light (200 to 800 nm). Using eq. (2) one obtains for the smallest wavelength a frequency

$$v = c/\lambda = (3 \times 10^8 \text{ m/s}) / (2 \times 10^{-7} \text{ m}) = 1.5 \times 10^{15} \text{ s}^{-1}. \text{ Consequently, } t_a = 1/v = 0.666 \times 10^{-15} \text{ s} = 0.666 \text{ fs},$$

An ultra-short time for an electron-charge to move one full cycle of 360°. For a crude estimate it is assumed that the conduction band in a 4-molecule polymer (smallest nanodomain) has a diameter of 0.5 nm, its circumference is close to 1.5 nm, the movement velocity is $v = (1.5 \times 10^{-9} \text{ m}) / (0.666 \times 10^{-15} \text{ s}) = 2.27 \times 10^6 \text{ m/s}$, far below the speed of light ($3 \times 10^8 \text{ m/s}$). The numbers for any other wave length may be determined similarly.

The photon wave is given in energy which should equate the energy in the excited state and may be written in terms of the processes prevailing in the circular nano domains (processes in the linear nanodomains are of no interest here, they are negligible at ordinary electric fields compared to those of the circular isomer in ordinary geomagnetic fields).

The magnetic field H (α) (see lower right of Figure 2) is directly dependent upon the current (I in Amperes, A) and shown largest in A and B of Figure 2 (but in opposing direction). When the current reaches its maximum (I_m), the voltage across the capacitance approaches zero. The tension across the capacitance is at its maximum (U_m) when this current is zero. We need to distinguish the functional angle α in the equations from the structural angle α' in Figure 2 (relationship defined in Appendix 3). We may now introduce the first energy relation given by

$$h\nu = \frac{1}{2} \int (C_e (U_m \cos \alpha)^2 + t_a (I_m \sin \alpha)^2) d\alpha \text{ for } \alpha \text{ from } 0 \text{ to } 360^\circ \quad (4)$$

Where c_e is the capacitance (in Farad, F) in the circular nanodomain (it is poorly defined in the linear isomer) and $t_a = 1/v$ (with t_a in s). There are two energy cycles over 360°.

The equivalence of the two terms in eq. (4) may now be combined with the Pythagorean trigonometric identity, $\sin^2\alpha + \cos^2\alpha = 1$, resulting in $h\nu = c_e U_m^2 = t_a I_m^2 \quad (5)$

In a coherent system with perfect mirrors and switching between wave and excited state (and back) taking place within less than 100 fs (t_s in Figure 2), this process could proceed forever. But in reality, nature replaces “forever” with a very large number (10^{10} s or even more [8]). At this point we do not know what processes actually determine this number. But such a large number in reference to the usual 10^{-9} s for a singlet excited state has vast implications for carriers of CDs, expanding biology dramatically.

If m is the number of pairs (shown in Figure 1 of [3]) cooperating in a CD, m could be as small as 1. However, according to other information discussed in [3] m is more likely close to 500. Figure 3 shows the case for $m = 2$ and the geomagnetic field in the vertical direction (time proceeds horizontally). Figure 4 shows a different kind of coherence for $m = 2$ but could theoretically extend over $m \gg 2$. The back-swing of the energy wave from the last nanodomains to the first may require special conditions for the speed of light in the overall coherence process.

The complication just mentioned could be overcome, if a second sequence of equal length is added with the wave state propagation in the opposing direction. There remains a problem of connecting the ends, as the wave state may be required to move normal to the plane shown in the Figure 4. Nanodomains at the ends may not be rigidly

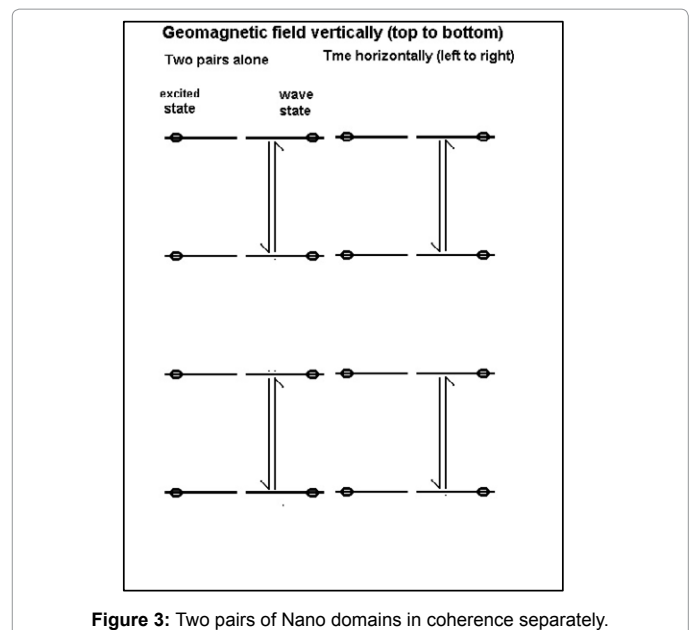


Figure 3: Two pairs of Nano domains in coherence separately.

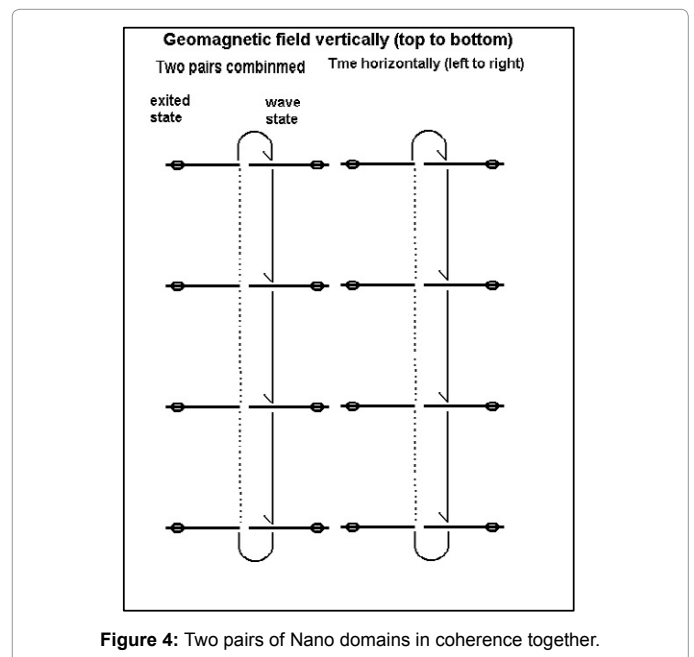


Figure 4: Two pairs of Nano domains in coherence together.

fixed, allowing them to flip rapidly; they could line up normal to the plane briefly connecting the two sequences.

If one wave state is able to move normal to the plane of Figure 4, there may be others which could produce a rectangle. There may then also exist rectangles of increasing size one within the other. Any number of solid rectangular layers may then align atop of each other and all in coherence. The result is a “permanent” cube-like arrangement (see also later).

In Figures 3 and 4 the magnetic field was shown as vertical. We did not consider that in nature the geomagnetic field is inclined to the vertical direction (except for small specific regions). There is almost always a vertical and a horizontal component. Thus humans and animals are known to move in reference to the vertical axis. This

variety in orientation facilitates a two-dimensional structure of “layers” of coherence.

Figure 3 shows two pairs of nanodomains in coherence separately. The system is essentially a doubling of the one-pair system in Figure 3 of [3]. Many more could co-exist in a whole coherence domain.

Figure 4 shows two pairs of nanodomains in coherence together one plane of nanodomains may have two or more pairs all acting together synchronously. There may be a problem with the feedback loop (dotted) from one side to the other, discussed extensively in the text.

Figure 5 provides an overview of the packing in coherence domains and shows the energy levels in nanodomains. The labels of the energy levels are derived from statistical thermodynamics (as “extent of degeneracy” [9]). Although independent, they are all linked together in the thermal energy exchange. In the coherence domains at least 1,000 nanodomains cooperate coherently with the oscillating process in synchrony, as was shown in Figures 1 and 2. While in Figures 1 and 2 this oscillating was shown in time, at the bottom of Figure 5 time is replaced by a second space dimension.

Figure 5 shows Packing of nanodomains in coherence domains. In the upper part the energy levels are shown in one water molecule, free in water. In the middle part the energy levels of a polymer (a nanodomain) are shown. The very rapid oscillation between the two states prevents thermal loss of excitation energy. The double-arrow pictures this oscillation. The lower part illustrates two configurations of coherent cooperation of nanodomains within coherent domains; assuming 1000 polymers in a coherence domain. Nanodomains are in the center of those rounded squares. “a” in eq. (1) may be labeled “coherence distance”. In the volume of a sphere its diameter corresponds to “a” and may be labeled “coherence diameter”, denoted by the squares with rounded corners. The assembly to coherence domains is described below.

We are assuming again a pair of nanodomains forms the smallest oscillating cycle, shown on the left. $4 \times 2 = 8$ nanodomains are involved. On the right is a filled square. In the third dimension, a stack of 1000 cooperating nanodomains result in 125 layers, thus creating a long stack in free solution; not necessarily found in living systems where

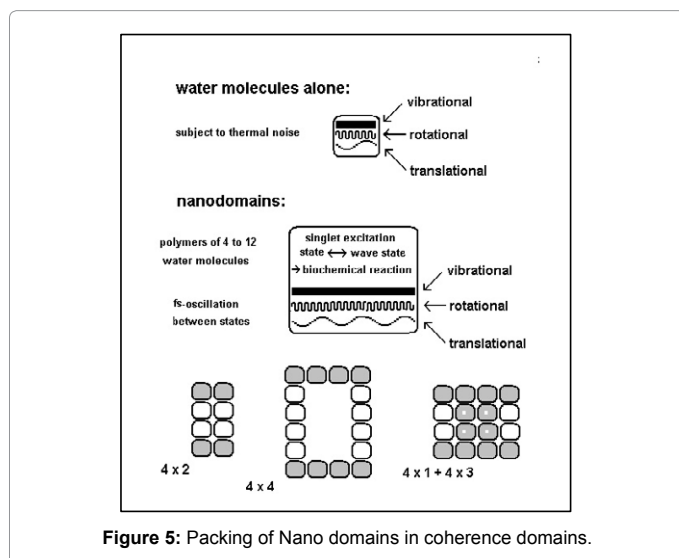


Figure 5: Packing of Nano domains in coherence domains.

Description	N_G	N_L	N_P	N_S
Innermost J = 1	2	8	8	125
For next J = 2	4	16	24	41.67
For next J = 3	6	24	48	20.83
For next J = 4	8	32	80	12.5
For next J = 5	10	40	120	8.33
For next J = 6	12	48	168	5.95

N_D = total number of nanodomains per coherence domain = 1000,
 N_G = total number of nanodomains per coherence group = 2,
 N_L = total number of nanodomains per coherence loop = $4 \times N_G$, a sequence,
 J = number of loops in a coherence plane = 1 and increasing by 1 sequentially,
 N_P = total number of nanodomains per coherence plane = $\sum J S_L$,
 N_S = total number of nanodomains per coherence stack = N_D/N_P .

Table 1: Rectangular layer of stack, given in number of nanodomains.

Description	N_G	N_L	N_P	N_S
Innermost J = 1	1	4	4	250
Innermost J = 2	3	12	16	62.5
Innermost J = 3	5	20	36	17, 78
Innermost J = 4	7	28	64	15.63
Innermost J = 5	9	36	100	10
Innermost J = 6	11	44	144	6.94

N_D = total number of nanodomains per coherence domain = 1000,
 N_G = total number of nanodomains per coherence group = 2,
 N_L = total number of nanodomains per coherence loop = $4 \times N_G$, a sequence,
 J = number of loops in a coherence plane = 1 and increasing by 1 sequentially,
 N_P = total number of nanodomains per coherence plane = $\sum J S_L$,
 N_S = total number of nanodomains per coherence stack = N_D/N_P .

Table 2: Square layer of stack, given in number of nanodomains.

some stacks are rather stationary i.e. in DNA (as found by Kim [9]). The next stacking cycle up is pictured at the bottom of Figure 5 in the middle. Here $4 \times 4 = 16$ nanodomains are involved. The full layer of nanodomains then consists of 8 (from the innermost cycle) + 16 = 24 nanodomains. In the third dimension of 1000 cooperating nanodomains then result in a stack of 41.67 layers (which could be 41 or 42, adjusting the total number involved).

The next cycle around has $4 \times 6 = 24$ nanodomains in the full sequence. Computational results for several sizes of layers are shown in Table 1. The stacking number gets smaller and smaller as the layer size gets progressively larger. Which shape is picked depends on the physiological requirements in an organism (laid down in its genetic material).

Instead of having a rectangular layer, a square layer may be considered at the bottom right of Figure 5. The first two “rings” are now shown one within the other with the inner ring denoted by a white square in the center of the each of each nanodomains. Table 2 shows the same calculations as shown in Table 1, now for a square layers. How these configurations are being used in physiology needs to be further determined in detail.

Expanded discussion

Is there any way by which one could establish the configuration of the coherence domain? In living systems, coherence domains have to fit into a coherence cavities (or coherence chambers). What do we know about the configuration of these cavities? How could they be made visible? How do square coherence domains adapt to their physiological coherence cavities?

The first row in Figure 1 shows only one of many possible steps leading to nanodomains. In the second row all eight molecules are completely aligned and in symmetry. When this occurs, the energy within all their states—the vibrational ones dominating—cooperating coherently, is causing a brake of an OH-bond, as shown in the third row. The resulting triplet state lives long enough to allow the radical electrons to delocalize and appear spread over the resulting polymer. This process is followed by the energy of one triple polymer transferred to the other: The energy donor returns to the ground state, while the energy acceptor forms a singlet excited state. This singlet state is first linear, but converts reversibly to a circular isomer (Figure 2). The circular isomer is the highly magnetizable nanodomain.

Above equation $a = m \lambda / 2$ shows the dependence of "a" upon λ (with usually $n = 1$). This would mean that "a" may change from 100 nm to 400 nm as λ changes from 200 nm to 800 nm for the usual range of coherent light. This is the classical relationship which was extended by Meyl [10]. The extension implies that for radiation distances (here "a") below λ the vacuum speed of light, $c = \lambda \nu$, may no longer be a constant. In the extreme case λ stays unchanged and c becomes proportional to ν . This difference can be resolved by the following experiment. If a coherence domain has the configuration of a cube and consists of 1000 nanodomains, the volume of a cubic coherence domain is given by $V = 1000 a^3$ (rounded). The concentration of nanodomains is then given by $c_{ND} = 2 m/V = 1000/V$ which may be converted to the molar concentration using Avogadro's number. The calculation shows that the largest experimental c_{ND} is currently near the limit of detection. Thus, special efforts would be required for the detection.

Figure 1 invites a related set of questions. Initially, each water molecule was shown with three electromagnetic frequency ranges, labeled vibrational (λ close to 1.35 μm), and rotational (λ just above 1 mm with total range not yet known) as well as translational (λ around 1 m with range not known). So far we only discussed one type of CD. Each one of the above frequency ranges should be associated with its own CD, possibly overlaying each other. The cell resonance of Meyl [10] may be associated with one of them, the infrared data of Brizhik et al [11] with another one.

How are these four types of coherence domains embedded into the human body (and in animals and plants)? There need to be cavities or chambers to keep them long term.

At this time, our work is focused on producing theory and laboratory methods to prove the existence of so called Coherence Domains which we suspect are the building block of Nature's information storage over a long period of time. This could lead to a novel technology platform useful anywhere the scientists are dealing with water (i.e. in chemical processes within our cellular environment).

As indicated earlier (first in Gariaev et al. [12]) DNA is involved in information storage for the work done in and outside the cell; on the other hand the cytoskeleton [13] is a network of long fibers that make up the cell's structural framework. Could these highways of interaction, as we believe, be involved in the formative impulses (determining cohesiveness between systems through derivative processes) [14]; for instance, store our intracellular water and its information in the form of energy states in CDs?

Conclusion

The actual existence of CD's and their possible role in chemical conversion, cell communication and systems control is far from being proven true. The case where the world of biological research could use

such an amazing application is very tempting, as it would open new avenues in medicine and other sciences as well. Still further research and understanding are needed [15].

Appendix 1: 2D-electromery in perspective

In this Appendix we shall discuss citations which claim that there is more to living systems than what classical biochemistry allows. We claim the same with one addition: Our analyses suggest that 2D-electromery should be seriously taken into account. So far, 3-D-processes were the main focus of biochemical reactions. To our knowledge, Kekule was the first investigator using 2D-electromery [16].

While Kekule's molecules were all in the ground state of electronic excitation, our molecules are in the electronic excited state, providing new characteristics. Figure 1 shows the initial sequence and appearance of the singlet excited state. Figure 2 illustrates the subsequent 2D-processes (with 2D-electromery, discussed in the main text). "Water in the protein interior serves important structural and functional roles and is also increasingly recognized as a relevant factor in drug binding. The nonpolar cavity in the protein interleukin-1 has been reported to be filled by water on the basis of some experiments." [17]. No data were reported on the state of water in the cavities.

Irrespective of their size, in Nature, from macro- to micro-systems there are operational similarities: space \rightarrow form \rightarrow energy \rightarrow information transfer; from galaxies to forming the fat droplets into the fat vacuole inside the cell [18-21]. "The structure (shape and size) of a CD depends, among others, on the architecture of the constituent surfactant molecule and the solution conditions (in our case the remainder of the bulk water) such as temperature, presence of impurities, etc." "The inter-particle interaction between molecules in and around the Nano domains has to be taken into account as well. The technique of Small Angle Neutron Scattering (SANS), microfluidic single-molecule detection (SMD) or single-molecule fluorescence resonance energy transfer (smFRET) approaches should be suited for the studies on CD's." [18], if suitable resonance energies can be found. Remember, NDs in CDs are highly diluted.

Liquid water is a very common and abundant condensed substance that is considered a fundamental ingredient for life more than any other, especially, in case of our demonstration; the information transfer within a negentropic system (Prigogine [22-25] and others) in the human body. Water is a "modulator", thus allowing for metastable equilibria between components of the intracellular cytoskeleton and extramural changes. To do so, the cytoskeleton's shape has to be most responsive to stored information that allows for vital compensation during changes. It is our opinion that modulator shapes are best expressed as a CD.

Emergent, system-wide patterns are said to be "self-organizing" over time because of the changes in structure which results from internal dynamics (i.e. bio molecular dynamics and cellular kinetics). Such self-organizing agents observed in complex adaptive system can range anywhere from the behavior of galaxies, a swarm of bees to molecules, they all are generating resonances that lead to waves and later to organization as already observed by Prigogine [22-25].

"Yet we do not fully understand many of its properties, especially when we probe it at the nanometer scale, although a lot of research has been done on this important system. Of particular interest for the reader should be the work done on hydrophobic channels because in this case water has been shown to escape from the channel altogether for entropic gain. However, these structures are difficult to probe

experimentally. Recent interest in fast DNA sequencing approaches has been crucial to the advancement of novel techniques to probe polymers in water environments at the nanometer scale; in particular, the proposal to sequence DNA by tunneling” [20]. And we cannot agree more.

Appendix 2: On the information copying process

Although, Czerlinski and Ypma described the involvement of vibrational, rotational and translational energy states in coherence, they report few details (some energy states are referred to as “extent of degeneracy” used in irreversible thermodynamics. We here describe what happens to these states in the process of nanodomain production. We only describe the statistical process operating in the background. This process is enhanced by various physical actions. Figure 1 shows this process starting with near-statistical distribution of eight water molecules - the smallest number which could participate to balance energies.

The question is what happens when information (held in electromagnetic waves of specific energies [and thus frequencies] in domains) is copied from the original domain onto another one. Is an energy quantum created out of nothing? Such creation would violate the first law of thermodynamics. Fortunately, there is Zero Point energy which would supply what is needed (although the details remain obscure).

Appendix 3: Structural angle α' defined

The relationship between structural angle α' and functional angle α needs to be defined. The latter (from 0 to 360°) is defined by the very rapid excited state behavior of the electron, as formulated in eq. (4). In contrast, α' describes what is actually shown in Figure 2 (lower half) for the circular isomer α'_m makes $\alpha'_m = 180^\circ$, on return $\alpha' = 0$ makes $\alpha = 360^\circ$. Angle α' starts at 0 and turns around at $\alpha'_m < 360^\circ$ (with the angular difference given by insulating layers), returning to 0 with the field pointing in the opposite direction. Or α moves from 180° to 360° while α' does from α'_m back to 0.

The smallest value for α'_m (180°) is given by the sequence presented in the upper part of Figure 2: One may say that the diameter of the superconducting band approaches infinity. There are other diameters between these limits where Nano domains aggregate in circles but are themselves only sections of circles. The electrons in sections of aggregate circles move coherently (and so does the energy-switching between states).

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