The Biophysical Basis of Water Memory

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Abstract: *J Benveniste had observed that highly dilute (and even in the absence of physical molecules) biological agents still triggered relevant biological systems. Some of these experiments were reproduced in three other laboratories. Further work showed that molecular activity in more than fifty biochemical systems and even in bacteria could be induced by electromagnetic signals transferred through water solutes. The sources of the electromagnetic signals were recordings of specific biological activity. These results suggest that electromagnetic transmission of biochemical information can be stored in the electric dipole moments of water in close analogy to the manner in which magnetic moments store information on a computer disk. The electromagnetic transmission would enable in vivo transmissions of the specific information between two functional bio-molecules. In the present work, the physical nature of such biological information storage and retrieval in ordered quantum electromagnetic domains of water will be discussed.*

1 Introduction: The pioneering experiments of Jacques Benveniste and his collaborators[1] left many biologists, chemists and physicists in an unecessarily confused state. Our purpose is to examine the notion of memory in water within a standard physics theoretical context of electromagnetic interactions. Ordered thermodynamic phase regions in space can be employed for storing information. Ferromagnetic ordering is routinely employed for storing memory information on computer disks. Wireless connections leave no doubt that information can be manipulated via electromagnetic waves with sources far from the information storage site. Recall the computer science definition of information memory storage[2]. If Ω denotes the number of states in a system, then the information capacity in "bytes" is defined as I = [lg Ω]/8 while Boltzmann defines the entropy as $S = k_B \ln \Omega$. It follows that one may look for memory capacity in those spatial physical regions of matter which contain entropy. In detail

$$I = \frac{1}{8\ln 2}\left(\frac{S}{k_B}\right) \approx (0.1803368801112 \text{ byte}) \times \left(\frac{S}{k_B}\right). \tag{1}$$

The biological polymer molecule which is best studied[3] with regard to memory properties is DNA. In human beings, it is believed that a four letter genetic program of size ~3 Gigabyte is stored on each DNA molecule. The code is written on the molecule in a highly fragmented fashion. If one includes so called junk segments, then it has been estimated that the junk information capacity is ~100 Gigabyte. We argue below on thermodynamic grounds that the thermal DNA memory capacity is comparable to junk fragment estimates. Of course, memory capacities alone describe only very crudely the subtle nature of biological code. In this regard we note the recent work[4] in which a loop function (subroutine) was inserted into a DNA genetic program within a yeast cell. The modification of the DNA program was induced by exposure to galactose. After many cell divisions, the loop function (subroutine) remained intact *without galactose* nor without any other sort of molecular trigger.

2. Memory in the DNA Polymer Molecule: To illustrate thermodynamic reasoning about information and entropy we consider the DNA molecule. The normal coiled state of the DNA molecule can become uncoiled. It is experimentally possible to hold two points of a long molecule apart with optical tweezers and measure the molecular tension τ. If L denotes the distance between the two points, then the free energy F at temperature T obeys

$$dF = -SdT + \tau dL \ \Rightarrow\ -\left(\frac{\partial I}{\partial L}\right)_T = \frac{1}{(8\ln 2)k_B}\left(\frac{\partial \tau}{\partial T}\right)_L . \tag{2}$$

From known variations of tension with temperature, we estimate for DNA molecules an information density of ~30 Gigabyte per meter comparable to information stored in so-called junk DNA.

3. Entropy and Information in Electrolytic Solutions: Water contains electric dipole ordered domains of radius R~100 nanometers due to a condensation of photons[5-7] interacting with molecular dipole moments. The ordered domains[8-10] yield an anomalously high water heat of vaporization q* per molecule. Let Δs be the entropy gained by a molecule when evaporated from the liquid into the vapor. The information per molecule due to ordered domains of water may then be measured employing

$$\Delta I = \frac{1}{8\ln 2}\left(\frac{\Delta s}{k_B}\right) = \frac{1}{8\ln 2}\left(\frac{q^*}{k_B T}\right) \approx 2.938\frac{\text{byte}}{\text{molecule}} \approx 23.50\frac{\text{bit}}{\text{molecule}}. \qquad (3)$$

The anomalously high heat of vaporization implies a high degree of memory storage capacity per molecule. Similarly, the partial entropy per molecule of an ionic species dissolved in an aqueous electrolyte[11,12] stores ~4 bytes or ~32 bits of information per ion which is sufficiently high as to expect such ions to be attached to an ordered water domain. Such an increase in the bulk coherent ordering volume of quantum hydration captured by an ion allows for semi-permeable membranes which can either pass an ion through a small gap or forbid such passage depending in part on the state of order in the ion attachment. Such passage through or rejection from semi-permeable membranes based on information (or equivalently entropy) constitutes a *program* for biological cells closely analogous to polymer DNA based programs. These have about the same order of magnitude for biological information capacity density, far surpassing information densities present in human artificially fabricated computer architectures.

4. Diamagnetic water: The magnetic properties of water are of equal interest to its electrical polarization properties. It is possible to float a small ferromagnetic needle over and above the surface of pure water. The magnetic needle floatation trick is most often demonstrated with perfect diamagnetic low temperature type one superconductors. The analogous floating of a magnetic needle above the water surface is due to the partial diamagnetic expulsion of Faraday magnetic field lines from pure water. For a single water domain of radius R and volume $V = 4\pi R^3/3$ containing N coherent electrons, the diamagnetic polarizability β may be estimated in terms of the electronic mean square radius as

$$\frac{\beta}{V} = \frac{N}{6V}\left(\frac{e^2}{mc^2}\right)\overline{r^2} = \frac{N}{8\pi}\left(\frac{r_e}{R^3}\right)\overline{r^2} \sim N\left(\frac{r_e}{8\pi R}\right) \sim 10^{-9}N \sim 1. \qquad (4)$$

A coherent ordered domain within water exhibits almost perfect diamagnetism. Yet the diamagnetism in water is weak. The reason is that magnetic flux tubes can permeate normal water regions just as magnetic flux tubes (called vortices) can permeate type two superconductors via their normal regions. Trapped magnetic flux tubes can also carry information and in particular can give directionality to otherwise isotropic pure water. This will (perhaps negatively) affect the directional nuclear magnetic resonance imaging of biological objects such as the human heart. Magnetic flux tubes trapped in normal water regions may have some positive and some negative medicinal consequences.

5. Del Guidice Domains and Zhadin Resonances: We describe as a Del Guidice domain, an ordered water domain with an ion of charge q = Z|e| moving smoothly over the domain surface. This was the object referred to above able to induce semi-permeable membrane (ionic switching) biological programs. Here we discuss magnetic properties of this object. An ion in a magnetic field has a Landau length L and a Larmor frequency ω:

$$L = \sqrt{\frac{\hbar c}{qB}} \approx \frac{2.56556408\times 10^{-4}\,\text{cm}}{\sqrt{|\text{Z}|}}\sqrt{\frac{\text{Gauss}}{B}} \qquad \omega = \frac{|ZeB|}{2Mc} = \frac{\omega_c}{2}. \qquad (5)$$

Note that the orbital Larmor frequency of an ion is one half the cyclotron frequency. For weak magnetic fields the cyclotron frequency ω_c is irrelevant to the physics of magnetic ion Zhadin resonances since the cyclotron radius is too enormous for orbit completion within the measurement apparatus. On the other hand the Larmor frequency ω is central for magnetic ion resonances in that orbit completion on the domain spherical surface of radius R is assured. It is also important to realize that in the domain of observed magnetic ion resonances, the Landau length $L \sim R$ so that a completely quantum mechanical treatment is required for the ionic motion over the domain spherical surface. For an ionic charge moving on the spherical surface of a Del Guidice domain with a magnetic field pointing from the south to the north poles, the relevant constrained quantum Hamiltonian H has the form

$$\Pi_\phi = p_\phi - \frac{q}{c}A_\phi = p_\phi - \frac{qR^2 B\sin^2\theta}{2c}$$
$$H = \frac{1}{2MR^2}\left(\Pi_\phi \frac{1}{\sin^2\theta}\Pi_\phi + \frac{1}{\sin\theta}p_\theta \sin\theta\, p_\theta\right). \qquad (6)$$

Angular momentum about the magnetic field axis is conserved as well as is energy. However, upon application of a time varying magnetic field one induces the Faraday law electric field,

$$curl\mathbf{E} = -\frac{1}{c}\frac{\partial \mathbf{B}}{\partial t} \quad \Rightarrow \quad E_\phi = -\frac{1}{2}R^2\sin^2\theta\frac{dB}{dt}. \qquad (7)$$

Since the square of the vector potential dominates the resonance conditions, harmonics of 2ω strongly affect the experimental ionic mobility experiments.

6. Conclusion: We have only briefly indicated how electric and magnetic dipole moments carry entropy and thereby information in aqueous electrolytes. Storing information allows biological properties to depend on past histories of electric and magnetic dipole moments within the water solvent. Since electromagnetic waves from sources far removed from the information storage can nevertheless have effects on such memory, it is clear that biological wireless connection may exist. Such notions as information memory capacity and biological programs are quite common in describing polymer genome analysis. It should not be surprising that such concepts should be present in other types of biochemical systems. For example, the communication between human memory residing in the human brain and the environment which evokes such memory relies on information carried by nerve cells whose electrical signals critically depend on ionic conduction. Although we are far from working out the relevant ionic electrical connections in life forms more complicated than (say) a lobster, it is very clear that electrolytic ionic information (i.e. entropy) plays an important role in the resulting electric circuitry.

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