Quantum Coherent Water, Non-thermal EMF Effects, and Homeopathy

How quantum coherent water may account for specific biological effects of very weak electromagnetic fields, and possibly homeopathy.

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I have been convinced since the 1990s that organisms are quantum coherent (see [1] The Rainbow and the Worm, The Physics of Organisms, ISIS publication); and more recently, that the quantum coherence of water is the basis of life (see [2] Life is Water's Quantum Jazz, ISIS Lecture), It is very exciting, therefore, to find that a quantum electrodynamic theory of coherent water may explain the energetics of life itself (see [3] Quantum Coherent Water & Life, *SiS* 51), as well as a special class of biological effects due to extremely weak electromagnetic fields (so-called non-thermal EMF effects), and possibly homeopathy.

Non-thermal EMF effects

Non-thermal electromagnetic field (EMF) effects are by definition those due to very low intensity fields that do not heat up the cells or tissues of organisms such that a rise in temperature could be detected. Such effects lie at the heart of the debate over the health hazards of EMFs from the extremely low frequency electricity mains supply to the radio waves and microwaves used in mobile telecommunication (see [4] Non-Thermal Effects , *SiS* 17).

Electromagnetic waves and the electromagnetic spectrum

Electromagnetic waves propagate through empty space at the speed of light, i.e., 300 000 kilometres per second, and include the light that enables us to see, which vibrates at frequencies of about 10^{14} cycles per second. They have both an electrical component and a magnetic component vibrating at right angles to each another.

The entire electromagnetic spectrum is extremely wide, ranging from waves that vibrate at less than one cycle per second, or one Hz (Hertz) – named after Heinrich Hertz, the German physicist who discovered electromagnetic waves in 1888 – to 10^{24} Hz. The corresponding range of wavelengths – speed/frequency – is from 3×10^{8} metres to 3×10^{-15} metre.

Above the visible spectrum are the ultraviolet rays, X-rays and γ-rays, the 'ionising' radiations that break molecules up into electrically charged entities, and known to damage DNA, causing harmful mutations.

Below the visible range are the non-ionising electromagnetic radiations, the safety of which has been debated for well over half a century.

The 'thermal threshold' fallacy

According to our regulators to this day, there is no conceivable mechanism whereby the very low intensity EMFs emitted by mobile phones and base stations or high tension power lines could have any biological effects, because the energy involved is below that of the random molecular motions *of a system at thermodynamic equilibrium*. I add the emphasis because everyone who has studied physics or chemistry at school will have recognized that organisms are anything but 'systems at thermodynamic equilibrium', so any regulator using that argument is grossly, if not wilfully ignorant, and should be immediately disqualified as a public menace.

In conventional (equilibrium) thermodynamics, the energy of a system is *nkT*, where *n* is the number of molecules in the system, *k* is Boltzmann's constant (1.3807×10^{-23} Joule per Kelvin) and *T* the absolute temperature in degrees Kelvin; this random 'thermal' energy is evenly distributed throughout the system and unavailable for doing work. So, any incoming energy less than *kT* - the kinetic energy of an individual molecule - is below the 'thermal threshold' at which useful work could be done, and can hence have no effect.

The 'thermal threshold' is a fallacy arising from the assumption that living organisms can be described in terms of conventional equilibrium thermodynamics; whereas by general consensus they are open systems meticulously organised and maintained *far away* from thermodynamic equilibrium. Useful work is done everywhere within the system because *coherent* energy is being mobilised for growth and development and for the myriad activities that life entails. In such systems, extremely weak electromagnetic fields with energies below the thermal threshold can indeed have macroscopic effects because these fields *affect an astronomical number of molecules simultaneously engaged in the same activity* – typically 10^{17} to 10^{20} molecules for a human weighing 70 kg.

Organisms are indeed coherent to a high degree, even quantum coherent, as research in my laboratory first revealed nearly 20 years ago [1]. Living organisms are liquid crystalline; all their molecules are aligned and polarized along the major body axis, *and* moving coherently together, including especially the 70 percent of water that forms dynamically coherent units with the macromolecules, and without which the macromolecules cannot function at all [1, 2]. Furthermore, organisms and cells, as well as molecules rely on electric and electromagnetic fields for intercommunication (see [4] The Real Bioinformatics Revolution, *SiS* 33), which is how living systems from bacteria to whales can function as perfectly coordinated and coherent wholes.

Specificity of non-thermal effects

There is abundant evidence of non-thermal biological effects going back decades. However, the picture is clouded by apparently conflicting results due to a failure to take into account the fact that EMF effects are often frequency-specific as well as specific for developmental stage (see for example [5] Brief Exposure to Weak Static Magnetic Fields during Early Embryogenesis Cause Cuticular Pattern Abnormalities in *Drosophila* Larvae, ISIS scientific publication).

Most intriguingly, the EMF effects often deviate from classical dose-response behaviour; in other words, they depart from the usual assumption that effect should go up linearly with field intensity, until a point of saturation. In particular, some effects can only be observed at a specific range of intensities, and disappear at both higher and lower levels. These intensity and frequency 'windows' simply stretched the imagination of many in the scientific community, and so the tendency is to dismiss those effects altogether, even by some of those who did experiments on non-thermal EMF effects.

Ion cyclotron resonance

The archetypal example of non-thermal EMF effects that exhibit both frequency and intensity windows was discovered in the laboratories of Carl F. Blackman [6] and Abraham R. Liboff [7] in the 1980s. In their experiments, they combined a static (DC) and an alternating (AC) magnetic field, which caused an increase in the concentration of free calcium ions in nervous tissues, in the form of a very narrow 'resonance' peak in the AC magnetic field, with the maximum corresponding to the 'cyclotron frequency' of Ca^{2+} ions.

Ions in a static and uniform (DC) magnetic field will typically move in a circle with a cyclotron frequency, f_c determined by its charge q, mass m, and the strength of the magnetic field $\boldsymbol{B}$:

$$f_c = (q\boldsymbol{B})/2\pi m \qquad (1)$$

An AC magnetic field that matches the cyclotron frequency gives special *ion cyclotron resonance* effects. Ion cyclotron resonance effects were extensively investigated in a number of laboratories [8]. The calcium cyclotron frequency was found to affect the calmodulin (calcium-binding protein) regulation of calcium ion concentration in solution and a host of biological functions: the motility of diatoms, the rate of cell proliferation in culture, melatonin synthesis in the pineal gland, calcium concentration in lymphocytes and thymus cells, the germination and growth of seeds, etc.

Ion cyclotron resonance was extended to other ions such as potassium on the rate of cell proliferation, and lithium and magnesium on animal behaviour.

But Mikhail Zhadin's research team at the Institute of Cell Biophysics of the Russian Academy of Science in Moscow attracted serious attention to the phenomenon when they showed that the ion cyclotron resonance could be demonstrated for a simple amino acid dissolved in water [9].

Ion cyclotron resonance for amino acids

Zhadin's team used a solution of glutamic acid (0.33 g/litre) in water adjusted to pH 2.85 with dilute acid in an electrolytic cell. A cubic cell (2 x 2 x 2 cm, 8 ml in volume) was filled with the solution. Gold electrodes with an area of 2 cm^2 were placed in the cell at a distance of 1 cm apart, and the potential difference between the two electrodes was adjusted to 80 mV with an external power supply. The cell was placed within two coils with one coil located inside the other, the axis of the coils coinciding with each other. The outer coil created the DC magnetic field, $\boldsymbol{B}$, and the inner coil made the AC field. The electric field between electrodes was perpendicular to the coils axis. The coils were located within a Permalloy chamber that shielded

all external fields. The DC magnetic field was 40 μT (microTesla), about the same as earth's magnetic field). The sinusoidal current through the inner coil generated the AC magnetic field of amplitude 0.02 μT. The AC field frequency was scanned in the range from 1 to 10 Hz with a speed of 0.05Hz/s. A baseline steady current of a few nA (nanoAmpere) was recorded under non-resonant conditions. At resonance, a transient sharp increase in current was found.

Initially, in order to find a minimum of the AC field at which an effect could be detected, the amplitude was increased in small steps starting with 10 nT (nanotesla). To their great surprise, a "quite prominent" brief peak of current through the solution was already found at 20 nT. There was only one peak, coinciding with the calculated cyclotron frequency of glutamic acid ion of 4.18 Hz. The peak of the current was 10–80 nT, and the rise time typically 0.5 s, while the decay time was 15 to 20 s. There was also an amplitude window, above or below which the effect was not detectable.

This striking effect has been reproduced by different laboratories, including that of quantum physicist Emilio Del Guidice at the University of Milan in Italy [10]. Initially, the success rate for producing the effect was about 20 percent, but increased to 70 percent in the most recently published experiments, where it was confirmed to be a field effect [11], as it could be produced even when the electrodes were placed outside the electrolytic cell.

Quantum electrodynamic explanation required

This apparent ion cyclotron resonance effect cannot be explained in terms of classical physics. Not only is the energy involved in the AC magnetic field some eleven order of magnitude smaller than the 'thermal threshold' or thermal noise, the calculated radius of the circular path taken by the ion at resonant frequency is metres, much larger than the dimension of the experimental cell in which the observations were made.

In order to explain this phenomenon, a quantum electrodynamic field theory was needed, as originally proposed by Giuliano Preparata [12] and elaborated by Del Giudice and other colleagues after Preparata's untimely death in 2000.

Quantum field theory predicts that liquids, being condensed matter with high density, are not governed by purely static local interactions such as H-bonds and dipoles. On the contrary, their binding is induced by radiative long range electromagnetic fields (EMFs). A collection of molecules interacting with the radiative EMF above a density threshold and below a critical temperature acquires a new minimum energy state different from the conventional where the oscillations of individual molecules are uncorrelated and the electromagnetic field is vanishing. The new minimum energy state is a coherence domain (CD) about 100 nm in diameter that oscillates in unison and in tune with an EMF trapped within it (see [3] for a detailed explanation).

How ion cyclotron resonance may be explained

According to the Preparata, Del Giudice and colleagues [13], liquid water is a two-fluid system consisting of a coherent phase (about 40 percent of total volume at room temperature) and an incoherent phase (see Figure 1).

Figure 1 Coherence Domain of water is a cube of about 100 nm at 0 ºC (left), shrinking to a smaller sphere as temperature increases (right)

In the coherent phase, the water molecules oscillate coherently between two electronic configurations in phase with a resonating EMF. The common frequency of the EMF and the electronic oscillation of the coherent phase is 0.26 eV (about 6.28 x 10^{13} Hz in the infra-red region); whereas the energy difference of the two electronic configuration of the coherent phase is 12.06 eV, which gives a wavelength of 1 000 A (100 nm). The oscillations span the whole available space within the CD.

Ions are excluded from the coherent phase. Instead, the electrolyte (dissolved ions) forms a coherent system within the noncoherent phase of the solvent. The ions oscillate in their respective Debye-Hückel cages (water molecules surrounding the ions due to dipole interactions). And these DH oscillations satisfy the quantum electrodynamical condition for coherence at all accessible concentrations. A major effect of the ion coherence is the elimination of interionic collisions, because all ions oscillate with the same frequency. So *kT* thermal noise is irrelevant.

The enormous radius attributed to the cyclotron orbit is also irrelevant, as that only applies to the high speeds attainable in the gas-like phase. In the condensed liquid phase, the speeds are considerably lowered, and hence the diameter of cyclotron motion much smaller, being that of the water CD.

The ions are driven into stable circular orbits around the CD equatorial plane so as to minimize their energy; the cyclotron frequency being $f_c = (q\boldsymbol{B})/2\pi m$ (Equation 1); the radius of the orbits being that of the water CD.

If now a weak AC magnetic field is superimposed, $\boldsymbol{B}_{ac}$ of frequency ω, sidebands are added to the fundamental cyclotron frequency, $f_s = f_c - n\omega$, with intensity proportional to $\boldsymbol{B}_{ac}$, so long as $\boldsymbol{B}_{ac}$ approaches zero (being very small). If $\omega = f_c/n$ at resonance, f_s vanishes, and this zero frequency become a translational movement out of the orbit, thereby contributing to an increase in electrical current, as observed (see Figure 2).

Figure 2 When BAC is small, the drift velocity of the ions out of the orbit around the water CD is small; when BAC reaches resonance levels, the drift velocity becomes large enough to break free of the orbit and enter into the general free reservoir thereby increasing the electrical current as observed

This explanation based on quantum coherent water accounts well in general for ion cyclotron resonance of electrolytes and small molecules. But many details remain unclear, especially the precise manner in which inorganic ions, and amino acids, not to mention peptides, proteins, and nucleic acids interact with water [8].

Most importantly, water within living organisms is different from bulk water, so how does ion cyclotron resonance work in that context? That remains to be explained.

Quantum coherent water and homeopathy

Could quantum coherent water account for homeopathy, more specifically, the memory of water in the form of pure EM signals originating from a DNA sequence that appears capable of 'informing' the synthesis of a precise replica of the original DNA sequence (see [14] DNA Sequence Reconstituted from Water Memory? *SiS* 51)?

According to the authors of the paper reporting on the phenomenon [15], which included Del Giudice, Giuseppe Vitiello and other colleagues, the CDs of water oscillate on a frequency common to the EMF and the water molecules, and this common frequency changes when energy is stored in the CD. The water CD effectively traps energy and exports it. When the oscillation frequency of the CD matches the oscillation frequency of some non-aqueous solute molecules present on the CD boundaries, these guest molecules become members of the CD and are able to catch the entire stored energy, which becomes activation energy enabling the guest molecules to engage in chemical reactions. There is indeed evidence that proteins and nucleic acids that share common functions or reactions do share a common EM frequency (see [16] The Real Bioinformatics Revolution , *SiS* 33).

Albert Szent-Gyorgyi had proposed 50 years ago that water surrounding biomolecules should be at the origin of the excitations of molecular electron levels responsible for chemical reactions [3]. So, if the ensemble of frequencies is able to attract the component monomer building blocks of a polymer because they are excited in the water CD, the polymer would be created from the monomers attracted to the CD, if they are present in the solution. Thus, it is possible, in principle, to induce the polymerization of monomers by supplying the monomers when the EMFs have the relevant frequencies (the EM information).

The essential role of electrolyte ions in regulating biochemical activity is well recognized. Ions close to water CDs are attracted by the EMFs trapped in the domains, so they orbit around the domain, moving at a circular speed proportional to the cyclotron frequency (see above).

The authors point out [15] that as DNA and proteins are polyelectrolytes, they are surrounded by a cloud of positive counter-ions with a cyclotron frequency in the interval between 1 and 100 Hz playing an important role.

The role played by the background of low frequency EMF is to provide a resonant alternating magnetic field in order to load energy in the water CDs. In higher organisms, such as the humans, the researchers suggest it is produced by the nervous system. Elementary organisms, such as bacteria, use environmental fields, such as the Schumann modes of the geomagnetic field. These modes are the stationary modes produced by the magnetic activity occurring in the shell whose boundaries are the surface of the earth and the conductive ionosphere. This acts as mirrors for the wavelengths higher than several hundreds of metres. These stationary modes should have a frequency ν_s, which in the ideal case is

$$\nu_s(n) = \frac{c}{2\pi R}\sqrt{n(n+1)} \qquad (2)$$

where R is the radius of the earth. The real earth-ionosphere cavity is not an ideal one, so the real frequencies are a bit lower than the values given by the equation. The peaks experimentally found are 7.83, 14.3, 20.8, 27.3 and 33.8 Hz.

Consequently, in order to produce the energy loading of CDs, the biological system should select ions having a q/m ratio that, given the local value of the static magnetic field $\boldsymbol{B}$ in the organism, fits in with one of the Schumann resonances. The local value of $\boldsymbol{B}$ is expected to be not much different from the earth's magnetic field, which is in the order of 50 μT.

The Schumann mode of 7.83 Hz appears resonant for the DNA signal [14, 15]. The extraction of ions from their cyclotron orbits, and by the conservation of angular momentum, produces a counter-rotation of the plasma of quasi-free electrons in the CDs, whose frequency depends on the number of involved ions (i.e., their concentration). It is the rotation of the plasma of the quasi-free electrons in the CDs that produces the observed EMS, which is why excitation is prevented by mu-metal, the authors suggested.

A decisive move towards quantum biology in understanding non-thermal EMF effects

The explanations are tentative and incomplete in many respects. How do the original DNA molecule and their counter-ions interact with the water CD? Studies on DNA and protein hydration have revealed dynamic coherence between hydration water and macromolecule (see [16] Dancing with Macromolecules, *SiS* 48); although it is far from clear whether studies on macromolecules in solution can tell us anything about the macromolecules inside the living cell (see [17] The Rainbow Ensemble, *SiS* 48). Nevertheless, the quantum electrodynamics theory of water provides a useful framework for further investigations that decisively moves biology away from classical towards quantum physics and a much better understanding of non-thermal EMF effects.

Indeed, non-thermal EMF effects was the subject of a recent 400-page monograph produced by the non-profit International Commission for Electromagnetic Safety [19], which formed part of the evidence submitted by Prof. Jacqueline McGlade and David Gee of the European Environment Agency to the Council of Europe Hearing on cancer risks from EMFs (see [20] European Environment Agency Highlight Mobile Phone Cancer Risks, *SiS* 51).

As the result of widespread concern, the European Parliament passed a resolution on EMF in 2009, which among other things, called for lowering exposure to electromagnetic fields, and for lower exposure limits to better protect the public from health hazards, a call repeated in 2011 (see [21] Wireless Phone Radiation "Possibly Carcinogenic", *SiS* 51). The current EMF limits for the UK are 360 μT for the general public exposure and 1 800 μT for occupational exposure [22], at which an increase in temperature in the exposed subject is not expected; totally disregarding non-thermal biological effects that can be observed at much lower levels.

I thank Dr. Emilio Del Giudice for helpful discussions and explanations on quantum electrodynamics of water.

Quantum Coherent Water and Life

Water is quantum coherent under ordinary conditions, according to a quantum electrodynamics field theory that may explain many of its most paradoxical properties including life itself.

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http://www.i-sis.org.uk/Quantum_Coherent_Water_Life.php

Water, the simplest, commonest compound on earth, also has the most complex properties and baffling 'anomalies' that make it essential for life. Generations of brilliant scientists have pitched their wits and sophisticated instrumentations in the hope of unravelling the secrets of water but in vain.

Perhaps the most significant discovery within the past 30 years is that water has quantum properties under ambient conditions, and may even be quantum coherent, as revealed by nuclear magnetic resonance measurements (see [1] Cooperative and Coherent Water and other articles in the series, *SiS* 48).

However, neither classical nor standard quantum theory predicts quantum coherence for water, largely because they ignore quantum fluctuations and the interaction between matter and electromagnetic field, which are taken into account in a quantum electrodynamics (QED) field theory.

Quantum fluctuations and coupling between matter and electromagnetic field in QED indeed predicts quantum coherence for liquid water even under ordinary temperatures and pressures, according to Emilio Del Giudice and his colleagues at Milan University, who have been researching this problem since the 1990s. Their theory suggests that interaction between the vacuum electromagnetic field and liquid water induces the formation of large, stable coherent domains (CDs) of about 100 nm in diameter at ambient conditions, and these CDs may be responsible for all the special properties of water including life itself [2-5].

Quantum electrodynamics of condensed matter and water

Quantum field theory explicitly recognizes an extended vacuum field – 'zero point field' – interacting with matter, as well as quantum fluctuations whereby energy in the vacuum field in the form of photons could be captured by matter. Quantum field theory combines Heisenberg's uncertainty principle in quantum mechanics with the energy-matter equivalence of Einstein's special relativity [6]; in other words, $\Delta E \sim 1/\Delta t$ is combined with $E = mc^2$.

Quantum field theory began in the 1920s and 1930s with the work of Max Born, Werner Heisenberg, Paul Dirac and others, and later, Richard Feynman and Freeman Dyson. But standard quantum field theory still does not explain water adequately.

In standard quantum field theory, the energy levels of material systems are shifted by their interaction with the fluctuations of the electromagnetic (EM) fields in the vacuum. The first clear example was the "Lamb shift", the energy of an electron surrounding the proton in a hydrogen atom is slightly lower than the value calculated from the atomic theory based on

purely static forces. Although this shift is very small, it provided evidence of the quantum vacuum fluctuation that has to be understood within the framework of quantum electrodynamics. In the case of the hydrogen atom, the effect is due to the interactions between the electric current of the electron orbiting the nucleus and the fluctuating electromagnetic field of the surrounding space (vacuum).

For a collection of particles, the usual approach is to apply the Lamb shift to each particle separately. While this is correct for very low density systems like gases, where the distance between any two particles is larger than the wavelength of the relevant fluctuating fields coupled to the systems, dense systems – condensed matter or liquids and solids - show entirely different behaviour.

When energy is absorbed from the vacuum field, the particles will begin to oscillate between two configurations. In particular, all particles coupled to the same wave-length of the fluctuations will oscillate in phase with the EM field, that is, they will be coherent with the EM field. The total energy of the system, E_{tot}, is a combination of the energy of the fluctuating EM field, E_{fl}, and the energy of excitation of the particles shifted from their ground state to the excited configuration, E_{exc}, plus the E_{int} of the Lamb-like shift,

$$E_{tot} = E_{fl} + E_{exc} + E_{int} \qquad (1)$$

While E_{fl} and E_{exc} are positive, E_{int} is negative. As shown by Preparata in 1995 [7], E_{fl} and E_{exc} are proportional to the number N of particles in a coherence domain (CD), but E_{int} is proportional to $N\sqrt{N}$. Consequently, there is a critical number of particles N_{crit} enclosed in a CD for which $E_{tot} = 0$. At that point, a phase transition occurs. The coherent oscillations of the particles in the CD no longer require any external supply of energy, and the oscillation is stabilized. Moreover, the CDs will begin to attract more molecules, and attract each other, thereby turning gas into liquid in a change of phase. With further increase in density, the system becomes a net exporter of energy because the stabilized coherent state has a *lower* energy than the incoherent ground state (see later).

The size of the CD is just the wavelength λ of the trapped EMF. The collective coherent oscillation of the molecules in the CD occurs between the coherent ground state and an excited state, whose volume, according to atomic physics, is wider than the ground state volume. The wavelength λ of the trapped EMF, and hence the size of the CD is about 100 nm, as it depends on the excitation energy E according to the equation:

$$\lambda = hc/E_{exc} \qquad (2)$$

The CD is a self-produced cavity for the EMF; the photon of the trapped EMF acquires an imaginary mass, and is therefore unable to leave the CD. Because of this self-trapping of the EMF, the frequency of the CD EMF becomes much smaller than the frequency of the free field having the same wavelength. This result applies to all gas-liquid transitions.

Coherent water is a source of almost free electrons

The special thing about water is that the coherent oscillation occurs between the ground state and an excited state at 12.06 eV (electron volt), which is just below the ionizing threshold at

12.60 eV, when $H_2O \rightarrow 2H^+ + O^{2-}$. A liquid water CD of 100 nm diameter contains millions of water molecules, and includes an ensemble (or plasma) of millions of almost free electrons that can be donated readily to electron acceptors dissolved in the water.

Some 60 years ago, the father of biochemistry, Hungarian born US scientist Albert Szent-Gyorgyi had already highlighted the importance of water for life [8, 9], and proposed that organized water existing close to surfaces such as cell membranes, is able to induce a very long lasting electronic excitation of the different molecular species present, thereby activating them and enabling their mutual attraction for reactions to take place (see later).

According to calculations performed by Preparata, Del Giudice and colleagues, the water CD is a quantum superposition of ground coherent state and excited state in the proportion of 0.87 and 0.13, giving an average energy of excitation per molecule of 1.56 eV. This is combined with the energy of the fluctuation electromagnetic field of 3.52eV and the interaction energy of -5.34 eV, according to equation (1), thus resulting in a *negative* energy of -26 eV per molecule. The renormalized (physically observable) frequency of the trapped EMF in the CD corresponding to 0.26 eV is 6.24×10^{13} Hz in the infrared region [3, 4].

Liquid water is therefore a two-fluid system [5] (in analogy with superfluid helium) consisting of a coherent phase (about 40 percent of total volume at room temperature) and an incoherent phase. In the coherent phase, the water molecules oscillate between two electronic configurations in phase with a resonating EMF. The common frequency of the EMF and the electronic oscillation of the coherent phase being 0.26 eV; whereas the energy difference of the two electronic configuration of the coherent phase is 12.06 eV, which gives the wavelength of 1 000 A (100 nm) of the coherence domain. The remaining 60 percent incoherent phase is extracted by thermal fluctuations from the coherent phase. The two phases have widely different dielectric constants: that of the coherent phase is 160, due to the high polarizability of the coherently aligned water molecules that are oscillating in concert; while the dielectric constant of the incoherent state is about 15. The externally applied electric fields are therefore only felt in the non-coherent phase.

This picture of liquid water, according to Del Giudice and colleagues, is reflected in the many observations supporting a two-state model of water (see [1, 10] Two-States Water Explains All? *SiS* 32), in which a substantial fraction of the molecules exist in hydrogen bonded state resembling that of ordinary ice. In fact, the hydrogen-bonds - short range interactions – are the consequence of the induced coherence in the coherence domains. But there is a rapid interchange of molecules between the CDs and the incoherent phase, hence it is impossible to detect CDs when the detection time is longer than the period of the oscillations, which is less than 10^{-13} s.

Quantum coherent water and life

Oxidation and reduction or redox reactions are the stuff of energy transduction in living organisms. It involves transfer of electrons from one substance (donor) to another (acceptor) to power all living activities. But where does the electron come from? It comes ultimately from splitting water in photosynthesis by green plants and cyanobacteria. However, it takes 12.60 eV to split water, an energy corresponding to soft X-rays, which is not what the green plants and cyanobacteria use.

More than 50 years ago, Szent-Gyorgyi [9] suggested that water at interfaces was the key. He proposed that water in living organisms existed in two states: the ground state and the excited state, and that water at interfaces such as membranes existed in the excited state, which requires considerably lower energy to split. A sign of the excited water is that a voltage should appear at the boundary between interfacial water and bulk water, which was indeed observed. This property of water enables energy transfer to take place in living organisms ensuring long-lasting electronic excitations. Szent-Gyorgyi's ideas were largely ignored by the scientific mainstream that became obsessed instead with molecular genetics.

The anomalous water at interfaces has been the subject of numerous research papers and reviews [11], and was already known in the late 1940s, as Del Giudice and colleagues point out [4]. Most if not all water in living organisms is interfacial water, as it is almost never further away from surfaces such as membranes or macromolecules than a fraction of a micron.

A vivid demonstration of interfacial water was achieved by Gerald Pollack's research team at University of Washington, USA (see [12] Water Forms Massive Exclusion Zones, *SiS* 23). Using a hydrophilic gel and a suspension of microspheres just visible to the eye, they showed that interfacial water apparently tens of microns or even hundreds of microns thick forms on the surface of the gel, which excludes the microspheres as well as other solutes such as proteins and dyes, and hence referred to as an 'exclusion zone' (EZ). Formation of EZ depends on fixed charges on the gel. When negatively charged gels were used, a potential difference of -150 mV was measured, in line with Szent-Gyorgyi's prediction, and protons were also excluded, becoming concentrated just outside the exclusion zone, giving a low pH there. Many other unusual characteristics were found [13]. EZ water is about 10 times as viscous as bulk water, it has a peak of light absorption at 270 nm, and emits fluorescence when excited by light at this wavelength. Illumination of EZ water especially by infrared increases the depth of the layer.

Del Giudice and colleagues [4] suggest that EZ water is in fact a giant coherence domain stabilized on the surface of the attractive gel. Inside the cell, the EZ would form on surfaces of membranes and macromolecules, as envisaged by Szent-Gyorgi. Because coherent water is excited water with a plasma of almost free electrons, it can easily transfer electrons to molecules on its surface. The interface between fully coherent interfacial water and normal bulk water becomes a "redox pile". In line with this proposal, EZ water does indeed act as a battery, as Pollack's research team demonstrated (see Liquid Crystalline Water at the Interface, *SiS* 39).

Del Giudice and colleagues also argue that water CDs can be easily excited, and are able to collect small external excitations to produce single coherent vortices whose energy is the sum of all the small excitation energies, turning the originally high entropy energy into low entropy coherent energy, which is trapped stably in the water CDs. This coherent energy in turn enables selective coherent energy transfer to take place as follows. All molecules have their own spectrum of vibrational frequencies. If the molecule's spectrum contain a frequency matching that of the water CD, it would get attracted to the CD, and become a guest participant in the CD's coherent oscillation, and settle on the CD's surface. Furthermore, the CD's excitation energy would become available to the guest molecules as activation energy for chemical reactions to take place. This selectivity may be the reason why out of a hundred different amino acids only 20 have been selected for making proteins in living organisms.

There is indeed independent evidence that molecules taking part in a biochemical reaction do share a common frequency, which is how they attract each other, essentially by resonating to the same frequency (see [15] The Real Bioinformatics Revolution, *SiS* 33). So it is likely that the reactants are attracted to the surface of the same water CDs, where the reaction will takes place, greatly facilitated by the excitation energy of the water CD. After the reaction, the energy released can also be absorbed by the water CD, shifting the CD's oscillation frequency, and hence changing the molecular species that become attracted to it, thereby in principle, facilitating the next reaction to take place in a chemical pathway.

Quantum coherence of water is really what makes life possible. It could also account for other strange phenomena such as the formation of a 'stiff' water bridge floating in the space just above two beakers of water placed next to each other and subjected to a strong electric field, as explained by Del Giudice and colleagues elsewhere [16], as well as low energy nuclear reactions (or cold fusion) [17], non-thermal electromagnetic field effects on biological system and possibly homeopathy (see [18] Quantum Coherent Water, Non-Thermal Effects, & Homeopathy, *SiS* 51).