PUBLIC HEALTH ASPECTS OF 5G

As opposing parties form around a public health question, there are often accusations that one or the other side (or both) selectively use data to support their opinion. This is often familiarly labeled as "cherry picking". As literature reviews must be limited in size and scope, this outcome seems partly inevitable. But there is one specific form of "cherry picking" that is particularly insidious, and contrary to sound scientific tradition.
A "cherry picking" procedure may limit, as a matter of policy, not only the literature it surveys, but also limit the variables it is willing of accept as relevant to human health to a single one. This is highly contrary to the practices of toxicology, where as many potential health impacts as possible are seriously examined to form an opinion on safe human exposure limits.
In the process of health impacts assessment of non-natural ElectroMagnetic Radiation (nnEMR), the International Commission on Non-Ionizing Radiation Protection (ICNIRP) has arbitrarily decided to limit acceptable evidence to heating effects. This effectively erected this principle to the level of a religious belief. And over the years, it has become obvious that this religion needed to be maintained at any cost.
We believe, as do many serious scholars, that this position is inspired by the limited perspectives of the military and of the engineering leadership, who have endeavored to impose their point of view on the whole human population.
The danger of using a sliver of science (heat) to guide decisions can be illustrated by a policy that would attribute human health risks solely on the basis of another simple variable, weight. In view of their size, how could we view viruses as a serious threat?

Whenever, this type of limitation is promoted, it is very likely to hide an agenda devoted to the protection of commerce (Smith A. The Wealth of Nations, 1776, Book IV, Chapter VIII, p. 145, paragraphs c29-30). See also, Maisch 2009 DR. The procrustean approach: setting exposure standards for telecommunications frequency electromagnetic radiation, Doctor of Philosophy thesis, Science, Technology and Society Program - Faculty of Arts, University of Wollongong. http://ro.uow.edu.au/ theses 3148.

ICNIRP has used two populist arguments to support its views. First, nnEMR, as used in telecommunications, is *non-ionizing*. Secondly, it is *too small*, from the point of view of energy content, to influence in any meaningful way biological systems.

The first argument is wholly based on the notion that nnEMR has to operate by the same mechanisms as ionizing radiation, such as is emitted by a nuclear power station. But the human body is already ionized, so whether radiation is capable of ionizing it or not is totally irrelevant to its health impacts. What IS relevant is whether this nnEMR is capable of meaningful interactions with biological systems.
nnEMR is a carrier of electromagnetic forces that have long been known from direct observations (Microwave Effects on Energy Metabolism of Rat Brain. Aaron P. Sanders et al. *Bioelectromagnetics* 1: 171-181 (1980); Effects of Continuous-Wave, Pulsed, and Sinusoidal-Amplitude-Modulated Microwaves on Brain Energy Metabolism. Aaron P. Sanders et al., *Bioelectromagnetics* 6:89-97 (1985)) to influence the performance of mitochondria, the biological energy centers of cells.

These observations can be understood in terms of the action of electric fields and of the more penetrating magnetic fields on charge transfers within and among the various molecular complexes (I to V) that constitute the supporting structures of oxidative phosphorylation. At a very basic level, nnEMR alters the mobility of protons and electrons within aqueous systems, and the pH of cell culture media, which inevitably triggers the release of calcium, a cellular alarm signal. The fields alter the behavior and chromosomes of cancer cells (Extra-Low-Frequency Magnetic Fields alter Cancer Cells through Metabolic Restriction. Ying Li & Paul Héroux. *Electromagnetic Biology and Medicine* 33(4):264-75. doi:10.3109/15368378.2013.817334, 2013, http://www.tandfonline.com/doi/full/10.3109/15368378.2013.817334).
From experiments, nnEMR also alter the survival of cells in terms of rates of apoptosis and necrosis, with a vigor superior to that of major physiological systems, such as oxygen (Magnetic Fields Trump Oxygen in Controlling the Death of Erythro-Leukemia Cells. Ying Li & Paul Héroux. *Appl. Sci.* 2019, Volume 9, Issue 24, 5318. https://www.mdpi.com/2076-3417/9/24/5318/pdf).

The second argument, that nnEMR at the commonly allowed (near thermal) levels of 10,000,000 µW/m², are too small to meaningfully influence biological systems, is incompatible with a rich body of experiments that show cancer, metabolic, calcium, reactive oxygen species and reproductive disturbances, from a lowest value of 0.001 µW/m² all the way up to ICNIRP's thermal limit of 10,000,000 µW/m² (www.Bioinitiative.org).
ICNIRP places a lot of emphasis on Power Density as a meaningful variable. Following this logic, it is interesting to determine how sensitive humans are to low power densities. To gain perspective on this subject, it is useful to remember that another type of radiation, sound, which shares many physical characteristics with nnEMR, is perceived by humans at levels of 1 pW/m² (or 0.000001 µW/m²). The table below gives specific values.

Variable	**Power Density (µW/m²)**
Threshold of Human Hearing (0 dB(A))	0.000001
Lowest reported biological action for nnEMR (www.Bioinitiative.org)	0.001
Lifetime exposure inducing some hearing loss (70 dB(A))	10
Lifetime professional exposure inducing compensable hearing loss in 25% of population (90 dB(A))	1000
ICNIRP thermally-based limit	10,000,000

You will note above, that the human body is one thousand times more sensitive to sound power density than it has ever been documented to react to nnEMR. This may be due to the fact that the human body has a specialized organ specifically designed to gather such radiation, the organ of Corti. It is also of note that the mechanisms that underlie the transduction (detection) of sound in the human ear are not completely understood. This has not prevented all societies in the world to legislate limits to excessive sound exposures, which implies that all details surrounding a health risk do not have to be known before protection is deemed necessary.

Because of its commercial agenda, a powerful community within our society has systematically rejected evidence proving clearly that changes need to be made in the way nnEMR should be allowed in the human environment.
This community proposes a future in which myriad devices (Internet of Things) converse within the space humans now occupy. This will lead to saturation to thermal levels of our vital space.
All of this is happening while clear evidence of carcinogenicity of nnEMR has been published in the past, and in recent years:
-Long-term, low-level microwave irradiation of rats. Chou 1992 CK et al. *Bioelectromagnetics*. 1992;13(6):469-96;
-Lymphomas in Emu-Pim 1 Transgenic Mice Exposed to Pulsed 900 MHz EM Field. Repacholi MH et al. 1997 *Rad Res* 147:631-640;
-National Toxicology Program (https://ntp.niehs.nih.gov/whatwestudy/topics/cellphones/index.html);
-Ramazzini Institute (https://ehtrust.org/wp-content/uploads/Belpoggi-Heart-and-Brain-Tumors-Base-Station-2018.pdf).

Sweeping under the carpet such science, specifically designed to investigate the toxicity of an agent, because certain groups do not like the results, is inacceptable to say the least. This is particularly troubling as there are alternatives to heavy reliance on wireless that are infinitely more attractive technically, and from the public health point of view.

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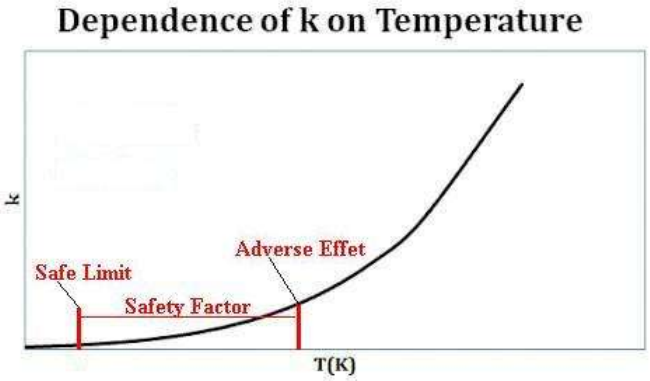
In response to:
Human Exposure to Radiofrequency Electromagnetic Fields A Proposed Rule by the Federal Communications Commission

2020-05-14

Arrhenius and FCC

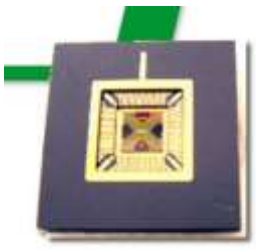
The FCC promotes ElectroMagnetic Radiation (EMR) health risk limits on the basis of work decrement thresholds associated with rising temperature in animals. This work decrement comes about from the triggering in the animals of disabling chemical reactions that have specific activation energies. The Arrhenius equation governs these reactions, which vanish very rapidly as temperature decreases (towards the left on the graph). For these reactions, the rate

$$k = Ae^{\frac{-E_a}{RT}}$$



constant of the reaction k resulting in pathology (work decrement) is connected to A, a constant for each chemical reaction, to E_a, the activation energy for the reaction, the universal gas constant R, and temperature (T) in Kelvin. Relying on this type of analysis introduces the assumption that, as a collection of thermal activation energies are not reached, sub-thermal exposures never cross the Lowest Observed Effect Level, consequently, no health effects will occur.
As a result, Power Densities as high as 10,000,000 µW/m² have been authorized in the environment by the FCC, on the basis that any interaction of the fields (205 nT free field equivalent) with biological systems will be drowned out by thermal noise.
This underlines that population protection is based on heat considerations only, as no other principle is involved in deriving maximum permissible exposures.

SpinTJ



There are tiny, commercially available SpinTJ devices with a bandwidth of 10 MHz that have magnetic field sensitivities of 0.2 nT (9.5 µW/m² free field equivalent) at 100 Hz and 0.002 nT (0.001 µW/m² free field equivalent) at 10 kHz (Link hereby incorporated by reference (Lhibr): http://www.micromagnetics.com/products_mtj_f_s.html). These sensitivities are respectively about one million (-60 dB) and 10 billion times (-100 dB) higher than the FCC power

density limits at cell phone carrier frequencies. The Fourier transform of a pulse train is the point-like convolution of (1) the repetition rate spectrum with (2) the spectrum of individual pulses. The transform, for symmetrical pulses with zero integral over time is zero at zero frequency (only), but it is not zero above that value. Consequently, if modulated cellular phone signals have even a small fraction of the energy (-60 or -100 dB) of their signals at frequencies below 10 MHz (for example, 8.3, 217 and 1750 Hz for GSM), these SpinTJ devices would detect such signals through electronic current changes within the devices.

The Micromagnetics SpinTJ (tunnel junction) magnetic sensors referred to above detect variations in the tunneling of electrons across very small distances of the order of 2 nm, and their sensitivity is due to angular deflections of the electron spin. In the semiconductor device, this is achieved by thin ferromagnetic layers capable of selecting for specific spin orientations on each side of a gap, while the intervening 2 nm gap allows for external magnetic field action (detection). This semiconductor device illustrates the sensitivity of electron tunneling to minute magnetic fields (0.2 nT at 100 Hz and 0.002 nT at 10 kHz) in the environment. SpinTJ acts by controlling electron spin on one electrode, allowing for interaction with environmental fields in the gap, and controlling again electron spin on the second electrode. Environmental fields alter the current transmitted through the gap.

We discuss below whether a mechanism similar to electron tunneling in SpinTJ is active in biological systems, and whether such a mechanism follows the same temperature dependency as the Arrhenius equation discussed above.

Essentially, we are trying to establish that low levels of heating cannot be used alone to determine health impacts, because a separate phenomenon, sensitive to EMR, but completely independent of heat, is also active.

Chiral Induced Spin Selectivity

Chiral Induced Spin Selectivity (CISS) is based on spiraling electron paths and a pure quantum mechanical effect, which lead to spin-selective transmission of electrons through biomolecules (Lhibr: Spin in Quantum Biology. Ron Naaman & David Waldeck. Biology, Review Essay, Vol. 3, No. 2, August 2017. https://inference-review.com/article/spin-in-quantum-biology). The phenomenon is important in biology, because chiral molecules are the building blocks of life. CISS depends on the chirality of the transfer medium, and on the molecular electric field acting on the electron. As a dynamic effect, CISS induces spin alignment as the electron moves, and even if spin polarization is partially lost when the electron resides on a cofactor, it is realigned again in the next hopping event (Spin Selectivity in Electron Transfer in Photosystem I. Itai Carmeli et al.02 July 2014. https://doi-org.proxy3.library.mcgill.ca/10.1002/ange.201404382). Spin polarization happens simultaneously with charge polarization, but as charge flow stops, spin direction is expected to randomize in a process that can take many μseconds in biomolecules (Lhibr: EMR spectroscopy of electron spin polarized biradicals in liquid solutions. Technique, spectral simulation, scope, and limitations. Closs GL & Forbes MDE. (1991) J Phys Chem 95:1924–1933).

Depending on the structural handedness of a region of a molecule (chiral handedness is conserved strictly throughout biology), electrons of a certain spin can traverse the molecule more easily in one direction than the other. Protein segments therefore act as spin filters, just like a magnetic material, all the while displaying no large-scale magnetic properties. CISS is significant whenever electrons transfer via tunneling with low transmission probability. The molecular structures with high spin-orbit coupling enhance current transmission by several orders of magnitude, and *the transmission is uncoupled from inelastic collisions and energy loss, such as heat.* This is because the directionality generated by the locking of electron spin and velocity suppresses backscattering by phonons or disorder: the electron's spin defines its transfer rate. Further, multi-electron reactions can use the spin filtering effect to favor particular reaction pathways. In hopping as opposed to tunneling, relative effects are added in serial systems.

Although this will not be discussed in depth here, interaction *between* protein is also influenced by spin and magnetism (figure from Lhibr**:** The electron's spin and molecular chirality – how are they related and how do they affect life processes? Karen Michaeli et al. Chem. Soc. Rev., 2016, 45, 6478—6487).
When chiral molecules interact, the
electronic charge in each of them is redistributed, and charge redistribution is accompanied by spin polarization so that homochiral interaction energies differ from heterochiral ones. Spin polarization enforces symmetry constraints on the biorecognition process between two chiral molecules.
Spin polarization, which in chiral molecules accompanies charge polarization, is a general way for quantum mechanics to affect biology. The coupling of the spin of an electron to its motion in chiral molecules and the resulting CISS have significant effects, *even at physiological temperatures*. For biomolecules, the effects are wide ranging, from the efficient transfer of electrons over relatively long distances, to enhanced selectivity of oxidation reactions, to the efficiency of enantioselective biorecognition.

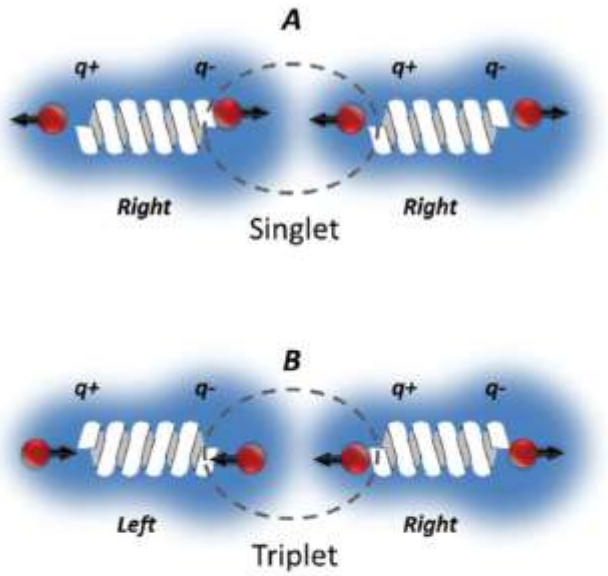
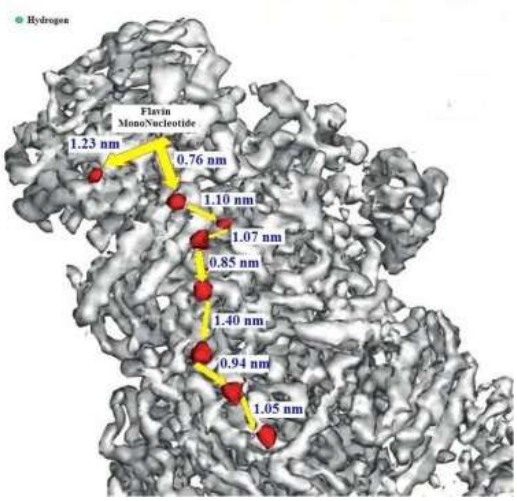
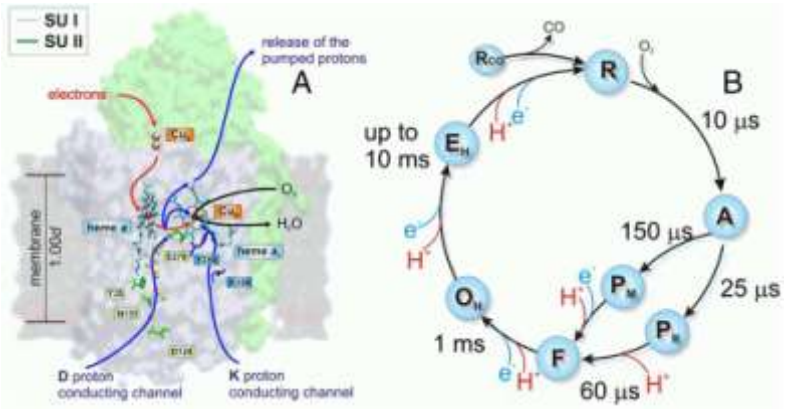


Fig. 7 (A) The diagram illustrates the interaction of two helices with the same handedness. Because of the induced dipole interaction charge q is transferred from one side of the helix to the other, and because of the CISS effect a spin polarization is generated (represented by a black arrow on the red ball). The side of the helix with excess electron density ($q-$) has a spin polarization parallel to the helical axis, and the side of the helix with a decrement of electron density ($q+$) has a spin polarization anti-parallel to the helical axis. In the region of electron density overlap (dotted circle-singlet surface), the two electron densities have a total spin polarization like that of a singlet state. (B) When the helical charge distribution is of the opposite chirality, its spin polarization points in the opposite direction, hence the arrows are pointed inward for the left handed helix. For the two helices of opposite chirality the overlap region (in the dotted circle-triplet surface) is characterized by two spins parallel to each other, like a triplet state.

Oxidative Phosphorylation



The figure at left is a molecular representation of Complex I, part of the set of 5 complexes supporting oxidative phosphorylation in mitochondria. The various red dots are electron sites, and the yellow arrows represent the physical distances that electrons tunnel through in order to maintain the flow of electrons through the molecule (Lhibr: Architecture of mammalian respiratory complex I. Kutti R. Vinothkumar et al., doi:10.1038/nature13686). Note that the tunneling process moves electrons 10 to 100 times further than the typical bond length of a molecule (a hydrogen atom is shown at upper left in the figure for comparison), because their spin and linear momentum are coupled, and cannot be reflected back without flipping their spin. This is highly improbable in organic molecules, but can come about from an external magnetic field, all while CISS effectively suppresses the influence of thermal fluctuations.



Another molecule sporting tunneling is Complex IV, and in the figure at left (Lhibr: Initiation of the proton pump of cytochrome c oxidase. Ilya Belevich et al. www.pnas.org/cgi/doi/10.1073/pnas.1010974107), we show the time delays measured for the tunneling to occur. These tunneling times, representing the intervals during which the tunneling processes in this particular molecule could be influenced, range from 10 µsec to 10 msec (100 Hz to 100 kHz). The movements of charges (electrons and protons) through Complexes I-V allow the accumulation of protons (of pH) into the mitochondrial inter-membrane space. This in turn supports the 180 kV/cm field needed to propel protons across Complex V, thereby fueling the synthesis of ATP.

As an aside, Complex V has a structure entirely similar to that of an electrical motor, and has its own specific sensitivity to external magnetic fields as a result of CISS enhanced by the mitochondrial inner membrane electric field. Spin selectivity has also been demonstrated in the transmission of electrons through duplex DNA (Lhibr: Spin specific electron conduction through DNA oligomers. Z. Xie et al., Nano Lett., 2011, 11, 4652–4655).

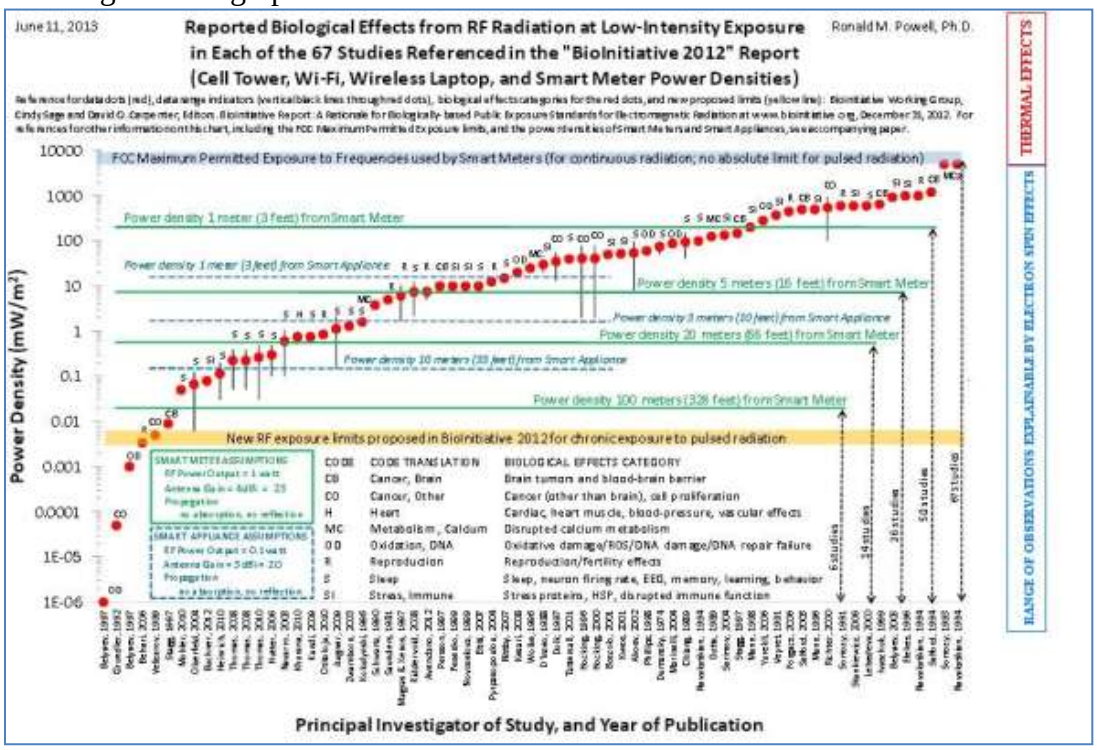
Effects on the Nervous System

It has long been known that non-thermal RF radiation is capable of inhibiting brain metabolism by classical mitochondrial indicators (NADH) that are entirely compatible with the mechanisms described above (Lhibr**:** Microwave Effects on Energy Metabolism of Rat Brain. Aaron P. Sanders et al. Bioelectromagnetics 1: 171-181 (1980); Effects of Continuous-Wave, Pulsed, and Sinusoidal-Amplitude-Modulated Microwaves on Brain Energy Metabolism. Aaron P. Sanders et al., Bioelectromagnetics 6:89-97 (1985)). The very specific statement in the 1980 article: "…microwave exposure inhibits mitochondrial electron transport chain function, which results in decreased ATP and CP levels in brain." is, furthermore, entirely compatible with more recent observations. Volkow (Lhibr**:** Effects of Cell Phone Radiofrequency Signal Exposure on Brain Glucose Metabolism. Nora D. Volkow et al. JAMA. 2011 February 23; 305(8): 808–813, doi:10.1001/jama.2011.186) showed in real-time that exposure to cell phone radiation increases use of glucose (which results from decreased use of oxygen). Salford and Persson (Lhibr**:** Nerve Cell Damage in Mammalian Brain after Exposure to Microwaves from GSM Mobile Phones. Leif G. Salford et al., Environmental Health Perspectives, volume 111, number 7, June 2003; Blood-brain barrier permeability in rats exposed to electromagnetic fields used in wireless communication. Bertil R.R. Persson et al. Wireless Networks, 3 (1997) 455–461 455) showed increased penetration of albumin in the brain of rats exposed to EMR. Reductions in ATP availability are an entirely likely explanation for the opening of gaps between pericytes of the brain intima.
Our own work on the ELF component of EMR radiation strongly suggests that variable EMR exposure increases the diversity of all significant human cancers (Lhibr**:** Extra-Low-Frequency Magnetic Fields alter Cancer Cells through Metabolic Restriction. Ying Li & Paul Héroux. *Electromagnetic Biology and Medicine* 33(4):264-75. doi:10.3109/15368378.2013.817334, 2013, http://www.tandfonline.com/doi/full/10.3109/15368378.2013.817334), and that the mere presence of EMR transitions adds a physiological stress, beyond the inevitable stress of reactive oxygen species, and attacks cells using different mechanisms (Lhibr**:** Magnetic Fields Trump Oxygen in Controlling the Death of Erythro-Leukemia Cells. Ying Li & Paul Héroux. Appl. Sci. 2019, Volume 9, Issue 24, 5318. https://www.mdpi.com/2076-3417/9/24/5318/pdf).
Recent results in animals, specifically the National Toxicology Program (Lhibr**:** https://ntp.niehs.nih.gov/whatwestudy/topics/cellphones/index.html) and Ramazzini Institute studies (Lhibr**:** https://doi.org/10.1016/j.envres.2018.01.037) as well as the IARC reports on ELF (2002) and RF (2011) have given considerable credence to non-thermal effects of EMR.

Biology cannot reproduce the details (such as the ferromagnetic layers) of the SpinTJ device, but it can structure molecules through evolution to favor metabolic electron transits using chirality and the Pauli Exclusion Principle (two electrons cannot occupy the same quantum state). Even if EMR is too small to heat, even if EMR is too small to affect intermolecular interactions significantly, spin polarization imposes a symmetry that affects the electron cloud overlap (Lhibr**:** Chirality-induced spin polarization places

symmetry constraints on biomolecular interactions. Anup Kumar et al. PNAS, arch 7, 2017, vol. 114, no. 10. ww.pnas.org/cgi/doi/10.1073/pnas.1611467114).

The fact that tunneling gaps are of similar size in SpinTJ and in mitochondrial complexes implies that electron spin is a variable relevant to the EMR environment, and that methods similar to those used in SpinTJ are present in nature. Should biological systems then have a sensitivity similar to the SpinTJ device, this sensitivity would explain all published observations reported by Powell from an analysis of the Bioinitiative report (Lhibr: https://bioinitiative.org/; https://skyvisionsolutions.files.wordpress.com/2013/06/powell-report-bioinitiative-report-2012-applied-to-smart-meters-and-smart-appliances_june_11_2013.pdf), as shown at the right of the graph below.



If the FCC becomes aware of a phenomenon that is relevant and important to the workings of biological systems that shows (1) a temperature dependence entirely different from the Arrhenius equation and (2) is sensitive to small electromagnetic fields substantially below the present heat-based limits, this gives ground to the FCC to promote a careful reassessment of its limits.

First, this CISS phenomenon is expected to be present at living systems temperatures and below, contrary to heat, which gains influence beyond living systems temperatures.

Second, this phenomenon was not taken into account before, and would justify converging on a different threshold of action (NOEL) for the determination of permissible exposure limits. This should incite the FCC to hold back on exposing the public to higher levels of radiation in the future, such as with 5G, and even to pull back on present limits.

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