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Prof. Martin Pall received his BA degree in Physics at Johns Hopkins University, with honors, Phi Beta Kappa and his PhD degree in Biochemistry and Genetics at Caltech, two of the top institutions in the world. His PhD training focused on how to determine biological mechanisms. The PhD training and the Physics have each been central to his ground breaking recent work on how low intensity electromagnetic fields (EMFs) impact the cells of our bodies and the many health consequences produced by that mechanism. Pall's Hirsch index is currently at 36 and has gone up rapidly since he "retired," showing high level of recognition for his research generally.

Pall's first paper on EMFs, published in 2013, showed that low intensity EMFs act by activating voltage-gated calcium channels (VGCCs). This was shown by findings that EMF effects can be blocked or greatly lowered by 5 types of calcium channel blockers, drugs specific for blocking the VGCCs. It was also shown by evidence of immediate increases in calcium signaling following EMF exposures and by further findings that the EMFs act by through the voltage sensor that controls VGCC opening (discussed further below). *Surprisingly, all of the EMFs ranging from the extremely high millimeter wave EMFs to be used with 5G through microwave frequencies, radiofrequencies, intermediate frequencies, extremely low frequencies including 50 Hz and 60 Hz from our power wiring through static electrical fields and static magnetic fields all act via VGCC activation.*

Much of Pall's subsequent work, in the 7 papers that have followed, has been to greatly expand our understanding of what EMF effects are produced via VGCC activation, how they are produced and why the VGCCs are so stunningly sensitive to activation by these weak EMFs. Before going into all of those important findings, let's look at how the VGCC breakthrough has been treated by the biomedical research community.

The 2013 paper, the first paper Pall published on the VGCC mechanism was placed onto the Global Medical Discovery web site as one of the best medical papers of 2013. At this writing, late January, 2019, the paper has been cited over 200 times according to the Google scholar database. This shows an unusual amount of interest from the scientific community, especially because that was Pall's first paper on EMFs and it involves a new paradigm of EMF action, and such new paradigm's usually face much inertia before they are widely accepted. Still, wide acceptance is not universal acceptance, even among the independent scientists working in this area. Pall has given 44 invited professional talks on EMFs over the past 6 years, again showing an unusual amount of interest. These include a talk at the French parliament on EHS, a talk at the Swedish parliament and a talk at the US National Institutes of Health. Two talks that are not included in the 44, because they were not invited talks, were given in September 2016 at one of the U.S. Senate Office Buildings and at the US FCC. Essentially everything that is discussed below with regard to EMFs, has been discussed in Pall's invited professional talks.

How the Physics Predicts the Very High Level VGCC Sensitivity to Low Intensity EMFs

The VGCC protein molecule contains a four domain structure with each domain carrying an alpha helix containing 5 positive charges. Those four charged alpha helices act

together as what is called the *voltage sensor*, the structure that responds to electrical changes across the plasma membrane to open the channel. It has been shown that not only 4 distinct types of VGCCs, but also a voltage gated sodium channel, potassium channel and chloride channel are all activated by EMFs, suggesting that the EMFs act on the voltage sensor. In plants, EMFs apparently act via activation of some other channels, known as TPC channels, which also contain a similar voltage sensor. The voltage-gated sodium, potassium and chloride channels apparently play only minor roles in producing EMF effects, so that to a first approximation, effects can be explained as being predominantly from VGCC activation.

How then can these very weak EMFs activate the voltage sensor? Pall has analyzed the known structure and location of the voltage sensor in the plasma membrane and based on two laws of physics, Coulomb's law and Ohm's law. The forces on the voltage sensor are calculated to be approximately 7.2 million times stronger than the forces on singly electrically charged groups in the aqueous parts of our cells and bodies. This means that the forces of these weak EMFs are stunningly strong and are therefore, more than sufficient to activate the VGCCs. Because heating is the basis of the current safety guidelines and heating is mainly produced by the forces on singly charged groups in the aqueous parts of our cells and bodies, this predicts that the current safety guidelines may allow us to be exposed to EMFs that are approximately 7.2 million times too strong. *The biology tells us that the VGCCs are the main targets of the EMFs. The physics tells us that the voltage sensor is the direct target and why it is so sensitive to these very weak EMFs.* The industry has been telling us for years that the electrical forces of these weak EMFs are too weak to do anything, and these calculations tell us why the industry has been completely wrong about this.

What Are the Biomedical Consequences of EMFs Activating the VGCCs?

The immediate consequence of VGCC activation is that one gets a very large influx of calcium ions into the cell through the plasma membrane that surrounds our cells, leading to very large increases in intracellular calcium $[Ca^{2+}]_i$. $[Ca^{2+}]_i$ increases produce in turn, different downstream effects that, individually or collectively produce each of the extremely well documented effects following EMF exposures. These explained effects include: 1. Neurological neuropsychiatric effects including insomnia, fatigue, depression, anxiety, loss of concentration, memory dysfunction, headache and other pain, stress, agitation and sensory dysfunction. These are all extremely common in our societies around the world and we know they can be caused by EMF exposures. 2. Reproductive effects including disruption of the structure of the testis and ovaries, lowered sperm count, lowered sperm motility and other measures of lowered sperm quality; lowered female fertility including lowered numbers of oocytes; increase spontaneous abortion; lowered levels of each of the three sex hormones; lowered libido. We have reason to think that these are already far advanced in every single technologically advanced country on earth. 3. DNA effects including single strand and double strand breaks in cellular DNA and oxidized bases in the cellular DNA. These have important roles in producing germ line mutation (producing mutant babies) and in causing cancer. 4. Oxidative stress and free radical damage. These have important roles

in causing essentially all common and many not so common chronic diseases. 5. Increased levels of apoptosis (programmed cell death) which has particularly important roles in causing the reproductive effects and also the neurodegenerative diseases including Alzheimer's. 6. Excessive $[Ca^{2+}]_i$, which is the cause of everything else. 7. Hormonal (that is endocrine) effects in all or almost all hormone systems. 8. Cancer which is caused by the DNA effects and other effects, leading to increases in not only initiation of cancer, but also increased tumor promotion and progression including tissue invasion and metastasis. 9. Therapeutic effects. 10. Life threatening cardiac effects producing aberrant electrical control of the heart beat. We are having an epidemic of young, apparently healthy athletes dying in the middle of an athletic competition, due to sudden cardiac death. Are these deaths caused by EMF exposures? 11. Breakdown of the blood-brain barrier. 12. Stress responses including heat shock responses (without heating) and AMPK activation. There are other effects, but where the primary role of EMFs in causation can still be questioned. These include: 1. Very early onset Alzheimer's dementia's and other dementias. We are seeing people age 30 coming down with Alzheimer's disease and young people said to be addicted to Wi-Fi internet connections coming down with what are called digital dementias. 2 & 3. Autism and ADHD, where late prenatal and early postnatal exposures seem to be the most important. The excessive $[Ca^{2+}]_i$ caused by such early exposures, is thought to disrupt the formation of synapses in the developing brain. 4. Electromagnetic hypersensitivity (EHS); while the mechanism of EHS is still somewhat uncertain, it is clear that excessive $[Ca^{2+}]_i$ produces sensitivity syndromes and that oxidative stress and sensitivity in the brain each have important roles in EHS. *Each of these 16 different important EMF effects and apparent effects can be caused by downstream effects of VGCC activation.*

Several of these effects are found to start slowly following most types of exposure but that the EMFs act cumulatively to produce more and more severe effects. The slow onsets are the types that are most difficult for us to perceive when we are experiencing them. As effects become more severe, they become apparently irreversible. Effects that show this pattern include the neurological/neuropsychiatric effects, the reproductive effects and the cardiac effects. The mutational consequences of the DNA effects are inherently cumulative and irreversible. Other effects that show this cumulative nature and apparent irreversibility are some but not other of the hormonal effects, Alzheimer's and other dementias and the perinatal exposures involved in producing autism and ADHD. The two cumulative effects that are of most concern to Prof. Pall are the neurological/neuropsychiatric effects which have high prevalence in our societies and the reproductive effects, which also have high prevalence. Either of these alone can produce extinction. We can estimate how long this is likely to take based on a combination of human epidemiological studies and rodent studies (where most things go approximately 15 times faster than they do in humans). Those rough estimates suggest that the neurological/neuropsychiatric effects could well lead to a disastrous crash in our collective brain function within 5 to 7 years in technologically advanced countries, simply based on the exposures we already have. Somewhat similarly, we could well see a reproductive crash essentially to zero within about 5 years based on our current exposures with some countries crashing much more rapidly. In either of these cases we will have no future. Of course increasing exposures beyond our current exposures from

5G, further expansion of 4G increased radar usage in cars and other exposure may be expected to produce much faster demise.

The Crash of Our Safety Guidelines: It Gets Even Worse

Our current safety guidelines are currently based on average intensities, usually averaged over 6 minutes and the estimated heating produced by these intensities in the tissues of our bodies. They do not take into consideration non-thermal effects including, of course, those produced via VGCC activation. However there are multiple, additional types of evidence that each show that these safety guidelines are deeply flawed, not only because of the cutoff levels used to claim safety of the exposures below that level, but equally or more importantly, the average intensities we are using are almost completely unresponsive of biological effects. How do we know this?

There are 13 reviews that have shown that pulsed EMFs are, in most cases much more biologically active than are non-pulsed EMFs *of the same average intensity*. This is very important for two distinct reasons. Each of our wireless communication devices communicate in part or in whole via pulsations. These devices are, therefore, potentially and Pall believes actually much more dangerous. Secondly, these findings also show that average intensities tell us very little about biological effects. It follows from the second of these consequences, that the safety guidelines are not measuring the right thing. What should we be measuring??

There is also a large, related literature showing that nanosecond pulses, defined as individual pulses that are between 1 nanosecond and 1 microsecond long, produce substantial biological effects. When these are averaged over 6 minutes, the intensities are so low that they are many orders of magnitude below the cutoff levels used in our safety guidelines. This is then, another situation where safety guidelines fail to predict biological effects. It should be added that there are studies where the effects produced by both nanosecond pulses and pulsed EMFs (described in the previous paragraph) have each been shown to be blocked by calcium channel blockers, showing that each of these act via VGCC activation.

There is, in addition, a large literature showing that there are intensity windows, that is specific ranges in intensities where EMFs produce maximum biological effects but where intensities that are *either lower or higher produce than those within the window, produce much lower effects*. What these findings show, is that dose-response curves are neither linear nor monotone (non-monotone means that effects do not always increase with increasing exposures nor do they always decrease with decreasing exposures). This contradicts the assumptions of the industry and regulatory agencies that dose response curves are linear or, at least monotone. Some of these intensity windows have been shown to occur at average intensities 3, 4 or 5 or more orders of magnitude below the safety guideline cutoffs. So again, the industry and regulatory agency assumptions that there is an average intensity below which we are always safe and above which we are a substantial risk of effects is shown to be false, such that the whole structure of the regulatory system is deeply flawed.

There is also a large literature where specific research groups have examined multiple cell types using identical methodologies and found that different cell types differ widely in how susceptible they are to microwave or other frequency radiation. This means that any regulatory scheme that just uses physics to predict biological effects, as is the case with our current safety guidelines, is inherently deeply flawed. It also means that biological safety testing which is the only reliable to test for safety or lack thereof, should focus on using cells in culture that are known to be highly sensitive to EMFs and are grown in a way that maintains that high level sensitivity. Pall has published two papers providing information on how such testing can be done.

There are two other issues that are each important, but possibly only in certain contexts. There are studies that have shown that certain very specific EMF frequencies, are frequency windows producing maximum effects at extremely low intensities, but shifting the frequency by only a very tiny amount produces vastly lower effects. These have been interpreted in terms of resonance effects with a target. In recent years, Dr. Belyaev has been the most active scientist in this area of research. There have been no studies done, to my knowledge, as to whether the voltage sensor may be the target of such resonance effects. It is not clear that most of the exposures we have are greatly influenced by these frequency windows. However it has been argued that the 2450 MHz frequency used for Wi-Fi is close enough to such a frequency window to be of concern. Pall has, however, another concern. These very specific frequency windows can be used to make microwave weapons vastly more biologically active. Currently, human populations are completely undefended, either physically or legally from such microwave weapons and military or diplomatic personnel may also have little or no defense, as well.

The last area of concern here is that artificial EMFs are all polarized whereas most natural EMFs are non-polarized. Polarized EMFs have the property that the forces they produce on electrically charged groups are much greater than those produced by non-polarized EMFs. It follows from this that the voltage sensor will be much more sensitive to activation by polarized EMFs. Pall's main concern about this is not with regard to the regulatory scheme but rather with regard to the apparent corruption of the scientific literature. Since about 2003, most if not all industry sponsored experimental studies have used reverberation exposure chambers to expose rodents or cell in culture to EMFs, to assess possible effects. However, these exposure chambers greatly decrease polarization and some of them may also produce substantial amounts of destructive interference, with both of these greatly lowering any effects seen. When such studies have been touted either by the industry or by regulatory agencies, this will have the effect of corrupting their assessment of the literature.

Dr. Pall's final statement:

Healthy skepticism is always the basis of the best science. I know that many of you will be skeptical, as you should be. It is the skeptics that most need to hear my talk and I welcome you to raise your most challenging questions.