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Meeting the imperative to accelerate environmental bioelectromagnetics research

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ABSTRACT

In this article, the author draws on his experience in the world of geospatial information technology standards to suggest a path toward acceleration of bioelectromagnetics science. Many studies show biological effects of extremely low frequency (ELF) and radiofrequency (RF) radiation despite that fact that the radiation is too weak to cause temperature changes in biological features. Considered together in worst case scenarios, such effects, many of which appear to have long latencies, could have potentially disastrous consequences for the health and safety of humans and wildlife. Other studies show no such effects, and in both cases, often there are significant research quality deficits that make it difficult to draw firm conclusions from the data. The progress of bioelectromagnetics science is retarded by a lack of standard data models and experimental protocols that could improve the overall quality of research and make it easier for researchers to benefit from omics-related bioinformatics resources. "Certainty of safety" of wireless devices used in digital communications and remote sensing (radar) is impossible without dosimetry standards that reflect the effects of non-thermal exposures. Electrical signaling in biological systems, a poorly funded research domain, is as biologically important as chemical signaling, a richly funded research domain, and these two types of signaling are inextricably connected. Entrepreneurial scientists pursuing bioelectronic innovations have begun to attract new funding. With appropriate institutional coordination, this new funding could equally benefit those investigating environmental effects of ELF and RF radiation. The author proposes a concerted effort among both bioelectronics technology stakeholders and environmental bioelectromagnetics science researchers to collaborate in developing institutional arrangements and standard data models that would give the science a stronger bioinformatics platform and give researchers better access to omics data. What is proposed here is essentially a bioelectromagnetics omics initiative.

1. Introduction

"We now realize that the phenomena of chemical interactions, and ultimately life itself, are to be understood in terms of electromagnetism." — Richard P. Feynman (Feynman, 1963)

Driven by significant public and private investment, an extraordinary amount of knowledge about biological molecular signaling has been acquired in the past two decades (Yao et al, 2015). Much of this has been in the context of omics initiatives that involve collaboration, data sharing, high throughput data collection and powerful bioinformatics computing. Related to this progress, there has been heavy investment in drug research and resultant progress and profits in pharmaceutical treatment of illness.

There has been much less investment and slower progress in learning about the role of electrical signaling in biology and how it might be applied in medicine. However, interest and investment in bioelectrical research and bioelectronics applications is beginning to ramp up (Moses, 2017). Two examples:

- Microsoft founder Paul Allen funds the Levin Laboratory (Levin Laboratory, 2018) at Tufts University. There, researchers study, among other things, electrical signaling in developing organisms, with a focus on morphology. For example, they have analyzed the electrical potentials that give rise to a frog's eyes as a frog embryo takes form. By duplicating those potentials at a point on the frog's emerging tail, they can cause an eye to grow on the tail (Pai et al, 2012).
- Pulse Biosciences, Inc. (Pulse Biosciences, 2018) went public in 2016. The company uses very brief, carefully calibrated electrical pulses to signal cells to go into apoptosis, or natural cell death. By this method, cancer cells and scar tissue cells can be instructed to simply disassemble for harmless reabsorption into the body, without inflammation or other distress (Nuccitelli, 2006).

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These researchers and their funders are at the leading edge of a new biotechnology development cycle. Bioelectronics could bring therapies that are more effective, less expensive, easier to monitor in patients and less prone to side effects than pharmaceuticals. Hybrid approaches involving both electrical and chemical interventions are very likely.

Increased investment in research into the role of electricity and magnetism in life processes could result in a safer electromagnetic field environment as well as important medical advances. Early planning for common standards and protocols, as in the omics sciences (genomics, transactomics, proteomics etc.) would accelerate this dual outcome.

Fields of study in biology that end in -omics apply large-scale bioinformatics to specific types of biological systems to understand how these systems work and interact with other systems. Omics usually involves institutional collaboration to facilitate sharing of data, algorithms, servers and research methods to maximize benefits of scale. Standards support sharing as well as economies of scale that motivate equipment vendors to invest in developing integrated, precise and high-throughput systems for data collection that they can sell to multiple research programs. See Section 4 below.

2. Difficulties in environmental bioelectromagnetics research

A key problem with environmental bioelectromagnetics research is that electric and magnetic field exposure conditions are often not reported in sufficient detail or measured with sufficient precision and accuracy to enable reproducible results (Dlugosz, 2013). In vitro studies are necessary to explore natural and induced phenomena, but the energies and induced effects are so small that confounding factors are difficult to avoid. For example, non-homogenous background electromagnetic field environments (1 Portelli, 2017) and temperatures within laboratory incubators (2 Portelli et al., 2013) have been shown to skew results, and this important critique can reasonably be applied to many studies that show or do not show biological effects. Theories of causation based on quantum level effects show great promise (Barnes and Greenebaum, 2016), but also introduce new factors that need to be measured and controlled in experimental protocols. As noted by Barnes and Greenebaum (Barnes and Greenebaum, 2016), it is also the case that organisms have systems for quickly repairing damage and maintaining homeostasis. These natural systems can conceivably make it more difficult to observe and quantify the subtle effects of weak externally applied fields.

Understanding effects induced by ambient fields requires measuring and experimentally controlling those fields, which are complex and highly dynamic. The wireless industry seeks to optimize bandwidth over limited spectrum to meet market demand for ubiquitous mobile access to an ever richer information environment. To accomplish this optimization, communication protocols and the fields they produce become increasingly complex, introducing new permutations of modulated amplitude, frequency, and polarity. Low energy near-field radars in smart cars, drones and other applications are anticipated, and they will have their own narrow frequency bands and patterns. Environmental radiation waveforms thus take increasingly varied and complex pulse shapes, with sharper spikes and perhaps wider dynamic range. As waves propogate on their way from transmitting antennas to receiving antennas and incidental contact with living beings, they interact in various ways with the external physical environment and also with each other, as shown in Fig. 1.

Cell phones and other hand-held wireless devices emit radiation in very close proximity to the body, and in this case the tissue interactions may be a more important issue than geoscale and mesoscale interactions. Each tissue type may have different absorbtion, refraction, induction, capacitance and resistance properties. In-transit interactions at any scale add both complexity and randomness to exposures that shift at their source from microsecond to microsecond or even nanosecond to nanosecond. Radiation impinging upon a studied biological feature or process may be random at some times and markedly pulse-patterned at other times.

Understanding cause and effect will require laboratory studies in which exposures – and also non-electromagnetic parameters characterizing exposed subjects – are carefully controlled in all their parameters. It will be necessary to develop unique test equipment that enables 1) controlled generation of emissions that mimic cell phone and WiFi emissions, creating exposures with varied permutations of frequency, amplitude, polarity and pulsing patterns, with attention to both electrical and magnetic fields, 2) elimination of weak ambient emission background noise and 3) precise control of other factors such as temperature. Development and deployment of this equipment will be expensive. Understanding cause and effect will also require epidemiological studies that document the effects of real world exposures, with their complex mixes of regular and chaotic variations of frequency, amplitude and polarity. Statistical exposure data will need to be accompanied by statistical data about non-electromagnetic characteristics of exposed living subjects This level of detail greatly exceeds the level of detail in previous epidemiological studies. Mobile devices with radiation sensors and bodily function sensors will make this possible, but the studies will nevertheless be expensive.

Overshadowing these research difficulties are controversial business and geopolitical influences that shape funding, regulation and public perception. (Hardell, 2017) The wireless industry's trade group (CTIA) and its member companies advocate before all levels of government to protect their interests with regard to wireless-focused policy issues. Through the industry's heavy investment in lobbying (CIO magazine, 2016), industry statements are frequently echoed in the policy statements of federal agencies. For example, "The FCC's position (FCC, 2018) is that there are no scientific findings that provide a definitive answer to the question of whether cell phone radiation causes cancer." (1 Slesin, 2016) This ignores thousands of studies that provide important evidence of cancer risk, and it ignores very strong evidence of health risks other than cancer, such as adverse effects on membrane function and oxidative stress. It also ignores an international appeal for precautionary measures that has now been signed by more than 230 scientists from 41 nations, all of whom have published peer-reviewed research on the biologic or health effects of electromagnetic fields (EMF) (EMFscientist.org). Local efforts include the CTIA's attempt to stop the city of Berkeley from enforcing an ordinance that requires cell phone retail stores to post basic precautionary advice. Many in the bioelectromagnetics research community point to evidence that industry has hampered the research effort, even while supporting research financially. See, for example, this commentary on the career of researcher N.P. Singh. (2 Slesin, 2017). It should be noted that increased public perception of health risks would also be troubling for governments that seek to promote the economic benefits of wireless communication and that also depend on radar for air traffic control, weather forecasting and national security.

Sources of research funding should be noted and considered in reviewing reported results, and readers should be aware that a papers' abstracts and conclusions may reflect the interests of those who paid for the research more than they reflect the actual experimental results (Huss et al., 2017). There is a need to ensure that all the research is performed with integrity and honesty and without industry influence.

3. Bioelectromagnetic data models and dosimetry

The complexity of radiofrequency radiation exposure raises questions about the SAR (specific absorbtion rate), which is the principal recognized measure of exposures' health risks. (SAR is discussed at length by various authors in a recently published book, *Dosimetry in Bioelectromagnetics* (Markov, 2017)). SAR is a measure of average energy absorbtion, typically measured over seconds or minutes across 1–10 cm^3 of brain tissue. If exposure is high enough to produce measurable gross temperature rise, the exposure is assumed to be capable of causing adverse effects that are known to be carcinogenic. This measure