ENVIRONMENTAL HEALTH TRUST
P.O. Box 58 Teton Village, WY 83025

January 15, 2019

Members of the School Board
Superintendent and Assistant Superintendents
Half Hollow Hills School District
Dix Hills, New York 11746

Dear Board Members and Administrators:

Today, I am writing to advise you of scientific grounds for taking action in your schools due to the major health concerns posed by wireless networks and cell phones in schools.

I was Founding Director of the Board on Environmental Studies and Toxicology of the U.S. National Research Council, and Founding Director of the Center for Environmental Oncology at the University of Pittsburgh Cancer Institute. President Clinton appointed me to the Chemical Safety and Hazard Investigation Board, and I am former Senior Advisor to the Assistant Secretary for Health in the Department of Health and Human Services. I founded the non-profit Environmental Health Trust in 2007 to provide basic research and education about environmental health hazards. Environmental Health Trust (EHT) is a nonprofit Think Tank and policy organization dedicated to identifying and reducing environmental health hazards. EHT provides independent scientific research and advice on controllable environmental hazards to local, state and national governments. Our scientific team is currently focusing on the health risks of radiofrequency radiation as an important public health issue.

Many people are unaware that cell phones and wireless laptops and tablets function because they are two-way microwave radios. A typical classroom might have the following scenario: every student has a laptop (which is typically tested for use 8 inches away from an adult male body); a cell phone in the pocket (which is also tested at a distance away from an adult male body); a network transmitter on the ceiling; and possibly a cell tower outside next to the sports field. All these devices emit radiofrequency microwave radiation that can readily penetrate into children's bodies and brains. *These devices have never been tested for safety with children.* Accumulating research indicates that long-term exposure to low levels poses a serious risk to children’s health.

Our published research provides new state-of-the-art radiation exposure brain modeling that confirms substantially higher radiofrequency radiation (RFR) doses occur in younger children as compared to adults. Research also indicates that with tablets and laptops children are more exposed than adults[1].

The 10-year $30 million National Institute of Environmental Health Sciences National Toxicology Program's (NTP) Studies of the Toxicology and Carcinogenicity of Cell Phone Radiation found that chronic exposure to RFR was associated with "clear evidence" of cancer due to the increased malignant schwannomas found in RFR-exposed male rats. The increases in brain (glioma) cancers and adrenal gland tumors were also considered evidence of an association with cancer. In addition, exposed animals had significantly more DNA damage, heart damage and low birth weight. The Ramazzini Institute published its findings that animals exposed to very low-level RFR developed the same types of cancers as reported by the NTP. These findings are corroborated by the research on humans that found people who use cell phones over 10 years "heavily" (defined in these studies as around 30 minutes per day) developed increased tumors—schwannomas and glioblastomas—of the same cell type as found in the NTP and Ramazzini Institute studies. Persons who started using cell phones under age 20 had the highest risk[2].

Due to these findings, numerous independent scientists are of the opinion that the weight of current peer reviewed evidence supports the conclusion that radiofrequency radiation should be regarded as a human carcinogen[3][4][5].

The range of impacts is growing. In addition to cancer, RF radiation also has been shown to impair immune system function, as well as impact gene and protein expression, cell signaling, oxidative stress, cell death, the blood-brain barrier and brain activity.

Yale University Chairman of Obstetrics/Gynecology Hugh Taylor, MD, PhD, has joined with physicians and experts in developmental biology in support of The BabySafe Project, which has created materials for health professionals and pregnant women, in order to promote awareness of the need to reduce exposures to cell phones and other sources of wireless radiation. Attesting to the

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[1] Ferreira, Juliana Borges, and Álvaro Augusto Almeida de Salles. "Specific Absorption Rate (SAR) in the head of Tablet user's." 7th Latin American Workshop On Communications 38 (2015): 1-464.

[2] Hardell, L. and M. Carlberg. Mobile phone and cordless phone use and the risk for glioma - Analysis of pooled case-control studies in Sweden, 1997-2003 and 2007-2009. Pathophysiology, vol. 22, no. 1, 2015, pp. 1-13.

[3] Peleg M, Nativ O, Richter ED. Radio frequency radiation-related cancer: assessing causation in the occupational/military setting. Environmental Research Vol 163, 2018, pp 123–133.

[4] Carlberg, Michael and Lennart Hardell. "Evaluation of Mobile Phone and Cordless Phone Use and Glioma Risk Using the Bradford Hill Viewpoints from 1965 on Association or Causation." BioMed Research International, vol. 2017, 2017.

[5] Miller AB, Morgan LL, Udasin I, Davis DL. Cancer epidemiology update, following the 2011 IARC evaluation of radiofrequency electromagnetic fields (Monograph 102). Available online Sep 6, 2018. https://doi.org/10.1016/j.envres.2018.06.043

seriousness of the health risks, Martha Herbert, MD, PhD, a Harvard pediatric neurologist, testified before the Canadian Parliamentary Health Committee, stating, "RF Radiation from wifi and cell towers can exert a disorganizing effect on the ability to learn and remember, and can also be destabilizing to immune and metabolic function."

FCC REGULATIONS ARE OUTDATED

Reliance on FCC compliance is non-protective, especially for children and pregnant women. FCC exposure limits were set more than 20 years ago and were based on decades-old research with no data on children's unique vulnerability. The Government Accountability Office published a 2012 Report that calls on the FCC to formally reassess its current RF energy (microwave) exposure limits, stating that the "FCC RF energy exposure limit *may not* reflect the latest research."

More than 240 scientists who have authored more than 2,000 articles on this topic appealed[6] to the United Nations to address "the emerging public health crisis" related to cell phones and other wireless devices, urging that the United Nations Environmental Programme (UNEP) initiate an assessment of alternatives to current exposure standards and practices that could substantially lower human exposures to non-ionizing radiation. These scientists state that "the ICNIRP guidelines do not cover long-term exposure and low-intensity effects" and are "insufficient to protect public health." They also state, "the various agencies setting safety standards have failed to impose sufficient guidelines to protect the general public, particularly children who are more vulnerable to the effects of EMF."

In response to this research, a growing number of public and private schools are removing the wireless networks from schools and implementing practical solutions. Examples of best practices in schools include:

- The United Educators of San Francisco (UESF), at a joint health committee with the San Francisco Unified School District, approved going forward with a resolution for safer technology. The resolution became official as of May 23rd, 2018, and the "Resolution on Enhancing Technology Safety in San Francisco Unified School District" and press release are on the UESF website.
- The Collaborative for High Performance Schools (the United States' first green building rating program especially designed for K-12 schools) has developed Best Practices for LOW EMF classrooms, which includes using corded (not cordless) phones, using ethernet connected (not wireless computers) in the classroom.
- "Guidelines for Safer Use of Wireless Technology in Classrooms" were developed for the New York State Teachers' Union, which later hosted a webinar on the risks of wireless technologies.

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[6] Blank, M., et al. "International Appeal: Scientists call for protection from non-ionizing electromagnetic field exposure." *European Journal of Oncology,* vol. 20, no. 3/4, 2015, pp. 180-2.

- The New Jersey Education Association recently published an article entitled, "Minimize Health Risks from Wireless Devices" and detailed several recommendations for reducing the health risks of technology: "Keep devices away from the body" and "hard wire all devices, including printers, projectors and boards." Please download a PDF with the recommendations at this link.

The American Academy of Pediatrics (AAP) is informing parents and the public about this issue in several ways. In addition to its letters to the US government, AAP issued ten recommendations on how to reduce RFR radiation exposure including, "If you plan to watch a movie on your device, download it first, then switch to airplane mode while you watch in order to avoid unnecessary radiation exposure."

Many countries and local governments have policies addressing wireless in the classroom:

- France has banned Wi-Fi in kindergarten and restricts Wi-Fi in school by having the wireless off as the default setting and teachers have wired (not wireless) computers for Internet access. In-school networks are being hardwired, and in situations where wireless is needed it is turned on only for a short duration in the classroom as needed and turned off after use. France also has banned cell phones in elementary/middle schools and started educating the public years ago with public health initiatives about how to reduce exposure.
- Cyprus has removed Wi-Fi from elementary classrooms and has a strong public awareness campaign educating parents, teenagers and pregnant women.
- Belgium banned cell phones manufactured for young children and also banned Wi-Fi in the kindergartens of Ghent.

Based on the accumulated scientific evidence showing biological effects, and policies devised by other nations, we recommend that the U.S. Department of Education and school districts such as the Half Hollow Hills School District do the following:

1. Raise school community awareness through new educational curriculum: Students, teachers and their families should be given information on wireless health risks and simple practical steps they can take to reduce exposure. It is important to teach children how to use technology both safely and more responsibly in order to protect their health and wellbeing.
2. Install a safe communication and information technology infrastructure in schools to meet educational needs: Solutions exist to eliminate and reduce exposures to wireless emissions—solutions that would significantly mitigate the health risk. Low-EMF Best Practices, which include safer hard-wire Internet connections (instead of Wi-Fi) and corded (instead of wireless) electronics and technology accessories and networks, also are faster and more secure.

Schools have a unique opportunity to maintain low-radiation environments through prudent technology choices and Low-EMF Best Practices, thus significantly reducing children's overall lifetime RF exposures. Considering that no research documents long-term exposure to low-intensity microwave radiation as being safe for children, and that the NTP study found a "clear" carcinogenic effect, the best approach is to reduce exposure to as low as feasibly possible.

Low-EMF Best Practices are the solution that allows for full communication, information access and learning tools use in the classroom while minimizing unnecessary health risks. Your district can thoughtfully integrate safe technology into every classroom while responsibly safeguarding the health of every generation.

I would be happy to provide or develop an online technical briefing to your senior staff to assist you as you make decisions today that will affect the health of students for the rest of their lives.

Please see our attached PDFs that summarize this issue along with our full recommendations for schools step by step.

Yours respectfully,

Devra Davis

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President and Founder
Environmental Health Trust
Visiting Professor of Medicine
The Hebrew University, Hadassah Medical Center
Associate Editor, Frontiers in Radiation and Health
Ehtrust.org

Questions and Answers on Wi-Fi and Cell Phones in Schools

Checklist on How to Reduce EMF and Wireless Radiation for Schools

Collaborative for High Performance Schools Low EMF Criteria

Questions and Answers about Wi-Fi in Schools

Why are doctors recommending wired - not wireless- internet networks in schools?

All wireless devices (including cell phones, cordless landline phone, any item with Wi-Fi or bluetooth capability, etc.) generate and emit an invisible electromagnetic radiation called radiofrequency (RFR). An ever growing amount of scientific **research documents show adverse effects from exposure to this radiation**—such as memory and sleep problems, headaches, cancer, and damage to reproduction, brain development, and DNA. These effects are found at very low levels of wireless radiation. The radiation penetrates deeper into children's brains due to their thinner skulls. Children's brains and immune systems are still developing, therefore they are more vulnerable to the effects.

Where can I find expert opinions about wireless effects on health?

Physician groups such as the **American Academy of Pediatrics**, the **Vienna Medical Association**, and **Athens Medical Association** are among the many **international medical organizations** that have issued recommendations to the public to reduce exposure to cell phone radiation. **Countries** such as France, Cyprus, and Israel have banned wireless in young children's classrooms. In several **letters** sent to school districts, physicians strongly recommended wired connections for technology in classrooms to eliminate unnecessary wireless radiation exposures.

The American Academy of Pediatrics recommendations include:

- Use text messaging when possible, and use cell phones in speaker mode or with the use of hands-free kits.
- Make only short or essential calls on cell phones.
- When talking on the cell phone, try holding it an inch or more away from your head.*
- Avoid carrying your phone against the body like in a pocket, sock, or bra. Cell phone manufacturers can't guarantee that the amount of radiation you're absorbing will be at a safe level.
- If you plan to watch a movie on your device, download it first, then switch to airplane mode while you watch in order to avoid unnecessary radiation exposure.
- Avoid making calls in cars, elevators, trains, and buses. The cell phone works harder to get a signal through metal, so the power level increases.

**EHT recommends holding the phone as far away from the head and body as possible and minimizing overall wireless use by preferring corded connections.*

The Collaborative for High Performance School Low EMF Criteria includes:

- Install a wired local area network (LAN) for Internet access throughout the school.
- Provide wired network connections for desktop computers, laptops, notebooks, and tablets.
- All wireless transmitters shall be disabled on all Wi-Fi-enabled devices.
- Install easily accessible hard-wired phones for teacher and student use.
- Prohibit use of standard DECT cordless phones operating at 2.4 GHz and 5.8 GHz
- Prohibit the use of cell phones and other personal electronic devices in instructional areas / classrooms.

How are students and staff exposed to this radiation in schools?

When students use a wireless computer or laptop, talk with a cell phone to the ear or even carry muted phones in their pocket, the radiation penetrates into their head and body. Wireless devices are always emitting radiation, even when they are not actively in use. Students are also exposed to RFR from wireless internet access points installed on or inside classroom ceilings and walls. Radiation emissions from the cell phones in combination with the emissions from each of the other wireless devices/accessories/networks in a school building create a cumulative daily RFR exposure for students, teachers, and staff.

What do teachers say?

The United Educators of San Francisco passed a **resolution** on safer technology; numerous teachers' unions are **calling** for reducing RFR exposures in schools to as few sources and as low emission levels as possible. The New Jersey Education Association published "**Minimize health risks from electronic devices**" recommending use of cords/cables/wires (rather than wireless) to connect devices and use of corded phones. The Ontario Secondary School Teachers' Federation Limestone District has **called** for a moratorium on Wi-Fi. The **Canadian Teachers' Federation** and **Ontario English Catholic Teachers Association** recommends avoiding and reducing RFR. New York's United Federation of Teachers has posted Dr. Moskowitz' "**Reducing Your Exposure**" and the **BabySafe brochure** for pregnant women.

Questions and Answers about Wi-Fi in Schools

What are best practices for schools to reduce this exposure?

Schools can ensure internet connectivity with safe corded connections, rather than wireless. Physicians **recommend** banning cell phones in schools for personal use and ensuring LAN networks, phones, printers, and technology systems are wired rather than wireless as best practices for schools. The **Maryland State Children's Environmental Health and Protection Advisory Council**'s Report advises reducing RFR as much as possible with wired internet connections. The Collaborative for High Performance Schools, a US green building rating program, has developed **LOW EMF criteria** for classrooms so that RFR is reduced to as low as possible. An example of a private school policy to reduce RFR exposure is the **Upper Sturt Primary School WiFi and Cell Phone Policy**. Castle Hill High School has developed **recommendations** to educate students on reducing cell phone radiation. FCC limits are not protective of health.

What actions are governments taking?

Numerous **governments** such as France, Cyprus and Israel are banning and/or restricting wireless in classrooms to reduce children's radiation exposure. The European Parliamentary Assembly issued **Resolution 1815** which recommends reducing EMF exposure to the public and recommends, "for children in general, and particularly in schools and classrooms, give preference to wired Internet connections, and strictly regulate the use of mobile phones by school children on school premises." Local governments have passed **resolutions** to promote wired rather than wireless internet and have **removed** and/or **halted** the introduction of wireless systems into school buildings.

What materials can I share with my school administrators?

The Santa Clara Medical Association Bulletin articles "**Wifi In Schools: Are We playing It Safe With Our Kids?**" and "**Shallow Minds: How the Internet and Wi Fi in Schools Can Affect Learning**" review the health impacts and doctors' recommendations. Both the New York State United Teachers (union) **webinar** and United Educators of San Francisco **webinar** are online videos about classroom wireless and health. Printable resources include the **New Jersey Education Association Recommendations**, **Dr. Moskowitz of University of California Recommendations**, **EHT's How To Reduce EMF in School Building Recommendations**, and **CHPS Low EMF Criteria**.

Resources

Physicians for Safe Technology
Joel Moskowitz PhD, Director of the Center for Family and Community Health School of Public Health at the University of California
The BabySafe Project
Grassroots Environmental Education Child Safe School
EHT Database of Worldwide Policies on Cell Phones, Wireless and Health
Reducing Electromagnetic Field Exposure in the Classroom: EHT Guide for Schools
Generation Zapped: A documentary film investigating children and wireless that schools can screen.

Peer Reviewed Published Science

Miller et al., "Cancer Epidemiology Update, following the 2011 IARC Evaluation of Radiofrequency Electromagnetic Fields (Monograph 102)" *Environmental Research*, 2018.

Carlberg, Michael and Lennart Hardell. "Evaluation of Mobile Phone and Cordless Phone Use and Glioma Risk Using the Bradford Hill Viewpoints from 1965 on Association or Causation." *BioMed Research International*, 2017.

NIEHS, National Toxicology Program Carcinogenesis Studies of Cell Phone Radiofrequency Radiation, Final Reports, 2018

Pall M., "Wi-Fi is an important threat to human health," *Environmental Research*, 2018

Avendaño, C., et al. "Use of laptop computers connected to internet through Wi-Fi decreases human sperm motility and increases sperm DNA fragmentation." *Fertility and Sterility,* 2012

Houston B., et al. "The effects of radiofrequency electromagnetic radiation on sperm function." *Reproduction*, 2016.

Shahin, Saba, et al. "2.45 GHz Microwave radiation impairs hippocampal learning and spatial memory: Involvement of local stress mechanism induced suppression of iGluR/ERK/CREB signaling." *Toxicological Sciences* (2017).

Megha, K., et al. "Low intensity microwave radiation induced oxidative stress, inflammatory response and DNA damage in rat brain." *Neurotoxicology*, vol. 51, 2015, pp. 158-65.

Yüksel, M. et al. "Long-term exposure to electromagnetic radiation from mobile phones and Wi-Fi devices decreases plasma prolactin, progesterone, and estrogen levels but increases uterine oxidative stress in pregnant rats and their offspring." *Endocrine*, vol. 52, no. 2, 2015, pp. 352-62.

Kostoff, Ronald N., and Clifford GY Lau. "Combined biological and health effects of electromagnetic fields and other agents in the published literature."*Technological Forecasting and Social Change* vol. 80, no. 7, 2013, no. 1331-49.

Yakymenko, Igor, et al. "Oxidative mechanisms of biological activity of low-intensity radiofrequency radiation." *Electromagnetic Biology and Medicine*, vol. 35, no. 2, 2016, pp. 186-202.

Redmayne, M. "International policy and advisory response regarding children's exposure to radio frequency electromagnetic fields (RF-EMF)." *Electromagnetic Biology and Medicine*, 2015.

Ferreira, Juliana Borges, and Álvaro Augusto Almeida de Salles. "Specific Absorption Rate (SAR) in the head of Tablet user's." *LAW On Communications* (2015)

Hedendahl, Lena K., et al. "Measurements of Radiofrequency Radiation with a body-borne exposimeter in Swedish schools with Wi-Fi." *Frontiers in Public Health*, 2017

Minimize health risks from electronic devices

By Adrienne Markowitz and Eileen Senn

Desktops, laptops, tablets, eBook readers, printers, projectors, smart boards, smart TVs, cellphones, cordless phones and wireless networks (WiFi) have become ubiquitous in schools. At their best, they are powerful tools for education. At their worst, they threaten the physical and mental health of teachers, paraeducators, secretaries, librarians and other school staff members and students who spend numerous hours using the devices.

Physical health risks from electronic devices include pain and tingling from repetitive strain injuries to the hands and wrists; pain in the neck, shoulders and back; dry, burning, itchy eyes, blurred vision and headaches; altered sleep patterns and next-day fatigue from exposure to blue screen light; distracted driving; and various health problems from exposure to radiation.

Mental health risks arise from stress due to raised expectations for multitasking, productivity and proficiency with devices; dealing with malfunctioning devices; student and colleague distraction from and addiction to devices; and intrusion of devices into nonwork time.

WiFi devices emit radiation

Radio frequency (RF) electromagnetic frequency (EMF) radiation is sent and/or received by the antennae of phones, routers and other wireless devices. RF radiation is capable of causing cancer, reproductive, neurological and ocular effects. The amount of radiation exposure received depends on the amount of time exposed and distance from the source. Radiation levels fall off exponentially with distance from antennae. If you double the distance, the radiation is four times less. If you triple the distance, it is nine times less, and so on. Children and developing fetuses are particularly at risk because their bodies are still growing. People with implanted medical devices are at risk for device interference.

Hazards and solutions

The most straightforward ways to minimize health risks are to use electronic devices in moderation and to maximize your distance from them. There are also specific solutions to specific hazards listed below.

Local associations should work with their UniServ field representative to negotiate solutions that are in the control of district administrators such as providing training and ergonomic equipment and hard-wiring devices. Individuals should take steps within their control, such as:

For repetitive strain injuries
- Use voice control/speech recognition.
- Use ergonomic alternatives to traditional mice and keyboards.
- Use as many fingers as possible when typing and both thumbs when texting.

For neck, shoulder and back pain
- Ensure an ergonomic workstation.
- When using a hand-held device, support it and the forearms.
- Avoid bending the head down or jutting it forward.
- Take frequent, short breaks from the device.
- Ensure good posture and change positions frequently.
- Stand and do stretching exercises.

For eye pain, blurred vision and headaches
- Use sufficient, but not excessive, lighting.
- Use assistive technology built into Apple, Android and Windows devices.
- Enlarge and darken the cursor and pointer.
- Enlarge the font; magnify the text.
- Use text-to-speech instead of reading.
- Use special computer glasses.
- Relax the eyes on a minibreak.

For altered sleep patterns and next-day fatigue
- Stop using devices at least one hour before bedtime.

For distracted driving
- Use hands-free devices, preferably speakerphones.
- Pull over and park.
- Let someone else drive.

For radiation exposure
- Keep devices away from the body and bedroom.
- Carry phones in briefcases, etc., not on the body.
- Put devices on desks, not laps.
- Hard wire all devices that connect to the internet.
- Hard wire all fixed devices such as printers, projectors and boards.
- Use hard-wired phones instead of cell or cordless phones.
- Text rather than call.
- Keep conversations short or talk in person.
- Put devices in airplane mode, which suspends EMF transmission by the device, thereby disabling Bluetooth, GPS, phone calls, and WiFi.
- Use speaker phone or ear buds instead of holding the phone next your head.
- Take off Bluetooth devices when not using them.

For stress
- Training in device use, assistive technology.
- Easy access to user manuals.
- Easily available technical support.

Adrienne Markowitz holds a Master of Science in Industrial Hygiene from Hunter College, City University of New York. Eileen Senn holds a Master of Science in Occupational Health from Temple University in Philadelphia. They are consultants with the New Jersey Work Environment Council, which is a frequent partner with NJEA on school health and safety concerns.

For more information

- **"Job stress: Is it killing you?"** *NJEA Review*, May 2012. *bit.ly/jobstress8*
- **"As schools lift bans on cell phones, educators weigh pros and cons,"** Kinjo Kiema, *NEA Today*, Feb. 23, 2015. *bit.ly/2b6eOr8*
- **Be kind to your eyes,** *NJEA Review*, September 2012. *bit.ly/2bdZnAp*
- **Computer workstations eTool,** Occupational Safety and Health Administration (OSHA). *bit.ly/2aJUeRw*
- **"Stretching Exercises at Your Desk, 12 Simple Tips,"** WebMD. *wb.md/2beOvUk*
- **"Cell phone facts and tips,"** Grassroots Environmental Education. *bit.ly/2bqpFQP*
- **"Radiofrequency and microwave radiation,"** Occupational Safety and Health Administration (OSHA). *bit.ly/2aR1TIY*
- **"Report of Partial Findings from the National Toxicology Program (NTP) Carcinogenesis Studies of Cell Phone Radiofrequency Radiation in Hsd: Sprague Dawley SD Rats (Whole Body Exposure)."** *bit.ly/2bqq8Cc*
- **"Low EMF Best Practices,"** Collaborative for High Performance Schools (CHPS), 2014. *bit.ly/2bs51Rx*
- **Microsoft Accessibility Center:** *www.microsoft.com/enable*
- **Apple Accessibility Center:** *www.apple.com/accessibility*
- **Google/Android Accessibility Center:** *www.google.com/accessibility/products-features.html*

NEW JERSEY EDUCATION ASSOCIATION

Cell phones and cancer

The National Toxicology Program (NTP) is conducting the largest set of laboratory rodent studies to date on cellphone RF radiation. The studies cost $25 million and are designed to mimic human exposure. They are based on the cellphone frequencies and modulations currently in use in the United States. The NTP studies are designed to look at effects in all parts of the body.

On May 27, 2016, NTP released a report with partial results of the studies. They found increased occurrence of rare brain tumors called gliomas and increases in nerve tumors called schwannoma of the heart in male rats. The released results are partial because more rat studies and all of the mouse studies will be forthcoming by 2017. The cells that became cancerous in the rats were the same types of cells as those that have been reported to develop into tumors in human cellphone users.

The EMF produced by cellphones was classified as possibly carcinogenic to humans by the World Health Organization in 2011. They found that long-term use of a cell phone might lead to two different types of tumors, gliomas and acoustic neuroma, a tumor of the auditory nerve.

CHPS
COLLABORATIVE FOR HIGH PERFORMANCE SCHOOLS®

2014 US-CHPS Criteria

New Construction and Renovation

Low-EMF Best Practices

Intent
Minimize exposure to extremely low frequency (ELF) magnetic fields.
EQ 15.1 – Low-EMF Wiring
EQ 15.2 – Low-EMF Best Practices

Numerous organizations recommend minimixing exposure to extremely-low frequency (ELF) electric and magnetic fields (EMF).

The US National Electrical Code (NEC) has been published since 1897 to promote safe electrical installations and to prevent fire hazards and electric shock. Wiring errors not only violate electrical code rules but may also cause unnecessary ELF magnetic field exposures. Wiring errors may occur in new construction or modernization projects, and inspections conducted by local code enforcement authorities may not detect the great majority of these problems.

In 2000, the expert panel of the California EMF Project (scientists of the California Department of Health Services on behalf of the California Public Utilities Commission) concluded based on the then-available scientific evidence that "*EMFs can cause some degree of increased risk of childhood leukemia, adult brain cancer, Lou Gehrig's Disease, and miscarriage.*"

In 2002, the International Agency for Research on Cancer classified **extremely low frequency magnetic fields** (ELF MF) as possibly carcinogenic (monograph volume 80).

In 2006, the IEQ Indoor Environmental Quality Project committee of the **US National Institute of Building Sciences** recommended to keep magnetic field exposure levels in occupied areas below 2.5 mG (250 nT), and preferably below 1 mG (100 nT).

In 2009, the **Austrian Sustainability Building Council** with support by the Federal Ministry of Transportation, Innovation and Technology released its latest version of the Total Quality Building Assessment tool. This green building rating system includes a criterion for low ELF magnetic field exposure levels: less than 1 mG (100 nT) "excellent", 1-2 mG (100-200 nT) "very good" (summary of threshold levels in English).

In addition, many education technology tools such as desktop computers, laptops, tablets, and other electronic devices are sources of electromagnetic fields. When used within close range of the human body, a student's exposure to electromagnetic fields such as ELF magnetic and electric as well as radio-frequency electromagnetic fields may increase considerably. ELF magnetic fields were classified as possibly carcinogenic by the World Health Organization (WHO) International Agency for Research on Cancer (IARC) in 2002, and radio-frequency (RF) electromagnetic fields (including mobile phones) were classified as possibly carcinogenic by the WHO/IARC in 2011. In order to reduce the potential for adverse effects due to these exposures, it is important in school environments with children to apply the precautionary principle "as low as reasonably achievable (ALARA)" by providing low-EMF classrooms, specifying low-EMF IT equipment and wired Internet access network technology, and establishing low-EMF user practices.

EQ 15.1 – Low-EMF Wiring		**Credit**	
		2 points	
Applicability	**Verification**		
All projects.	Design Review	Construction Review	Performance Review

Requirement

2 points	EQ 15.1	*No net current magnetic fields – Correct school wiring* The wiring in all school rooms shall be compliant with the currently adopted US National Electrical Code (NEC) in the local jurisdiction, and applicable state electrical code. All school rooms shall be free of the following common wiring errors: a. Improperly wired subpanels (neutral-to-ground bond); b. Incorrect three-way switch wiring; c. Incorrect wiring of switched outlet circuits; d. Neutrals from separate branch circuits that are connected anywhere beyond the panel of origin for the circuits; e. Neutral-ground shorts (intentional or inadvertent) anywhere in the system. The correctness of the wiring shall be checked in each room and the ELF magnetic field exposure measured levels (tRMS) comply with 1 mG (100 nT) in new construction and 2 mG (200 nT) in existing school modernizations, see the Austrian Sustainability Building Council (2009) – Total Quality Building Assessment Rating System as shown in Table 13 below.

EQ 15.2 – Low-EMF Best Practices		**Credit**	
		1 - 2 points	
Applicability	**Verification**		
All projects.	Design Review	Construction Review	Performance Review

Requirement

1 point	EQ 15.2.1	*Low EMF Best Practices for Computers* The District or equivalent governing body for a private school shall pass a resolution requiring: • Desktop computers, laptops, notebooks, and tablets be operated on a desk; operation of these devices on an occupant's lap or body is prohibited; computer workstation equipment must be greater than 2 feet from occupants. • Desktop computers, laptops, notebooks, and tablets be TCO-certified or laboratory tested to meet TCO Criteria "Mandate A.4.2" for EMF emissions. • Laptops or notebooks have an Ethernet port and a physical switch to conveniently disable all wireless radios at once and an adaptor with a 3-pin plug. • Only tablets that support a USB Ethernet adaptor for a wired network connection; operate tablets only in battery mode and not when plugged in.

OR 1 point	EQ 15.2.2	*Wired local area network (LAN) to reduce radio-frequency (RF) EMF* • Install a wired local area network (LAN) for Internet access throughout the school. Provide wired network connections for desktop computers, laptops, notebooks, and tablets. All wireless transmitters shall be disabled on all Wi-Fi-enabled devices. Provide wired input devices for computer workstations.
OR 1 point	EQ 15.2.3	*Wired Phones to reduce RF EMF in classroom* • Install easily accessible hard-wired phones for teacher and student use and prohibit installation and use of standard DECT cordless phones and cordless phones operating at 2.4 GHz and 5.8 GHz unless they have been laboratory tested to demonstrate that the cordless phone base station and handsets (whether placed in the charging station or not) do not emit RF EMF emissions in standby mode. • Prohibit the use of cell phones and other personal electronic devices in instructional areas / classrooms. Additionally, they shall be required to be powered off or be in airplane mode (sleep mode is not sufficient) except during fire-life-safety drills and incidents.

HARVARD MEDICAL SCHOOL

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TRANSCEND

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December 12, 2015

Montgomery County Schools
Carver Educational Services Center
850 Hungerford Drive
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cc Montgomery County City Council

Dear Montgomery County School District,

I am a pediatric neurologist and neuroscientist on the faculty of Harvard Medical School and on staff at the Massachusetts General Hospital. I am Board Certified in Neurology with Special Competency in Child Neurology, and Subspecialty Certification in Neurodevelopmental Disorders.

I have an extensive history of research and clinical practice in neurodevelopmental disorders, particularly autism spectrum disorders. I have published papers in brain imaging research, in physiological abnormalities in autism spectrum disorders, and in environmental influences on neurodevelopmental disorders such as autism and on brain development and function.

A few years ago I accepted an invitation to review literature pertinent to a potential link between Autism Spectrum Disorders and Electromagnetic Frequencies (EMF) and Radiofrequency Radiation(RFR). I set out to write a paper of modest length, but found much more literature than I had anticipated to review. I ended up producing a 60 page single spaced paper with over 550 citations. It is available at http://www.bioinitiative.org/report/wp-content/uploads/pdfs/sec20_2012_Findings_in_Autism.pdf and it was published in a revised and somewhat shortened form in two parts in the peer reviewed indexed journal *Pathophysiology (2013)*with the title: Áutism and EMF? Plausibility of a pathophysiological link." Please also see the appendix to this letter which contains a summary of this material and includes substantial scientific citations.

More recently I published an article entitled [“Connections in Our Environment: Sizing up Electromagnetic Fields,”] in *Autism Notebook Spring 2015* edition in which I summarized and personalized the information in the . In this article I describe how here is a whole series of problems at the cellular, sub-cellular and metabolic levels and immune levels that have been identified in autism. And interestingly, for every single one of those problems, there’s literature about how EMFs can create those kinds of problems.

The argument I made in these articles is not that EMF is proven to cause autism, but rather, that EMF can certainly contribute to degrading the physiological integrity of the system at the cellular and molecular level” – and this in turn appears to contribute to the pathogenesis/causation not only of autism but of many highly common chronic illnesses, including cancer, obesity, diabetes and heart disease.. Please see this article on page 24-25 at the link http://virtualpublications.soloprinting.com/publication/?i=252361

In fact, there are thousands of papers that have accumulated over decades –and are now accumulating at an accelerating pace, as our ability to measure impacts become more sensitive – that document adverse health and neurological impacts of EMF/RFR. Children are more vulnerable than adults, and children with chronic illnesses and/or neurodevelopmental disabilities are even more vulnerable. Elderly or chronically ill adults are more vulnerable than healthy adults.

Current technologies were designed and promulgated without taking account of biological impacts other than thermal impacts. We now know that there are a large array of impacts that have nothing to do with the heating of tissue. The claim from wifi proponents that the only concern is thermal impacts is now definitively outdated scientifically.

Radiofrequency electromagnetic radiation from wifi and cell towers can exert a disorganizing effect on the ability to learn and remember, and can also be destabilizing to immune and metabolic function. This will make it harder for some children to learn, particularly those who are already having learning or medical problems in the first place. And since half of the children in this country have some kind of chronic illness, this means that a lot of people are more vulnerable than you might expect to these issues.

Powerful industrial entities have a vested interest in leading the public to believe that EMF/RFR, which we cannot see, taste or touch, is harmless, but this is not true. Please do the right and precautionary thing for our children.

I urge you to opt for wired technologies in Montgomery County classrooms, particularly for those subpopulations that are most sensitive. It will be easier for you to make a healthier decision now than to undo misguided decisions later.

Thank you.

Martha Herbert, PhD, MD

Selected pertinent publications

Connections in our Environment: Sizing up Electromagnetic Fields by M.R. Herbert (published in Autism Notebook Spring 2015, pp.. 24-25) reviews in two pages key points of the more technical Herbert & Sage Autism-EMF paper

Herbert, M.R. and Sage, C. "Autism and EMF? Plausibility of a Pathophysiological Link". Part 1: *Pathophysiology* , 2013, Jun;20(3):191-209, epub Oct 4, PMID 24095003. Pubmed abstract for Part 1. Part II: *Pathophysiology,* 2013 Jun;20(3):211-34. Epub 2013 Oct 8, PMID 24113318. Pubmed abstract for Part II.

APPENDIX: MORE DETAILED SUMMARY OF THE PATHOPHYSIOLOGY

I became interested in the health and brain effects of electromagnetic frequency (EMF) and radiofrequency radiation (RFR) exposures in relation to my brain research because I was interested in how such exposures might alter brain function. In order to familiarize myself in more detail existing literature on the pathophysiological impacts of EMF/RFR, I coauthored a 40,000 word chapter in the 2012 update of the Bioinitiative, [1] and published an updated 30,000 word version of that paper ("Autism and EMF? Plausibility of a Pathophysiological Link") in 2013 in two parts in the peer reviewed journal *Pathophysiology.* [2,3] My intention was to assess the plausibility of an association between increasing incidence of autism spectrum disorder and increasing EMF/RFR exposures. Rather than directly address the epidemiological issues, I looked at the parallels between the pathophysiological features documented in autism and the pathophysiological impacts of EMF/RFR documented in the peer-reviewed published scientific literature.

I will include here a brief summary of the paper (prepared for a lay audience) of the features of EMF/RFR that I reviewed (with citations at the end of this letter):

- EMF/RFR stresses cells. It lead to cellular stress, such as production of heat shock proteins, even when The EMF/RFR isn't intense enough to cause measurable heat increase. [4-6]
- EMF/RFR damages cell membranes, and make them leaky, which makes it hard for them to maintain important chemical and electrical differences between what is inside and outside the membrane. This degrades metabolism in many ways – makes it inefficient. [7-15]
- EMF/RFR damages mitochondria. Mitochondria are the energy factories of our cells. Mitochondria conduct their chemical reactions on their membranes. When those membranes get damaged, the mitochondria struggle to do their work and don't do it so well. Mitochondria can also be damaged through direct hits to steps in their chemical assembly line. When mitochondria get inefficient, so do we. This can hit our brains especially hard, since electrical communication and synapses in the brain demands huge amounts of energy.
- EMF/RFR creates "oxidative stress." Oxidative stress is something that occurs when the system can't keep up with the stress caused by utilizing oxygen, because the price we pay for using oxygen is that it generates free radicals. These are generated in the normal course of events, and they are "quenched" by antioxidants like we get

in fresh fruits and vegetables; but when the antioxidants can't keep up or the damage is too great, the free radicals start damaging things.

- EMF/RFR is genotoxic and damages proteins, with a major mechanism being EMF/RFR-created free radicals which damage cell membranes, DNA, proteins, anything they touch. When free radicals damage DNA they can cause mutations. This is one of the main ways that EMF/RFR is genotoxic – toxic to the genes. When they damage proteins they can cause them to fold up in peculiar ways. We are learning that diseases like Alzheimer's are related to the accumulation of mis-folded proteins, and the failure of the brain to clear out this biological trash from its tissues and fluids.
- EMF/RFR depletes glutathione, which is the body's premier antioxidant and detoxification substance. So on the one hand EMF/RFR creates damage that increases the need for antioxidants, and on the other hand they deplete those very antioxidants.[1, 16]
- EMF/RFR damages vital barriers in the body, particularly the blood-brain barrier, which protects the brain from things in the blood that might hurt the brain. When the blood-brain barrier gets leaky, cells inside the brain suffer, be damaged, and get killed. [1, 16, 17]
- EMF/RFR can alter the function of calcium channels, which are openings in the cell membranes that play a huge number of vital roles in brain and body. [18-27]
- EMF/RFR degrades the rich, complex integration of brainwaves, and increase the "entropy" or disorganization of signals in the brain – this means that they can become less synchronized or coordinated; such reduced brain coordination has been measured in autism. [28-40]
- EMF/RFR can interfere with sleep and the brain's production of melatonin. [41-43]
- EMF/RFR can contribute to immune problems. [44-50]
- EMF/RFR contribute to increasing stress at the chemical, immune and electrical levels, which we experience psychologically. [51-57] [17, 58-62] [63-68]

Please note that:

1. There are a lot of other things that can create similar damaging effects, such as thousands of "xenobiotic" substances that we call toxicants. Significantly, toxic chemicals (including those that contain naturally occurring toxic elements such as lead and mercury) cause damage through many of the same mechanisms outlined above.
2. In many of the experimental studies with EMF/RFR, damage could be diminished by improving nutrient status, particularly by adding antioxidants and melatonin. [69-72]

I understand that the concept of electromagnetic hypersensitivity is not always well understood in the medical and scientific communities. Indeed, the inter-individual variability is perplexing to those who would expect a more consistent set of features.

But given the range of challenges I have listed that EMF/RFR poses to core processes in biological systems, and given the inter-individually variable vulnerability across these symptoms, it is really not surprising that there would be subgroups with different combinations of symptom clusters.

It also appears to be the case that the onset and duration of symptoms or even brain response to EMR/RFR can be variable. This again is to be expected given the mediation of these symptoms through a variety of the above-listed pathophysiological processes, many of which differ in scale (ranging from molecular to cellular to tissue and organ) and time course of impact. The different parts of the body also absorb this energy differently, both because of their biophysical properties and as a function of their state of health or compromise thereof.

Here is a list of subgroups of symptom clusters identified by a group of German physicians, t exemplifies these variability issues:

Group 1 no symptoms
Group 2 sleep disturbance, tiredness, depressive mood
Group 3 headaches, restlessness, dazed state, irritability, disturbance of concentration, forgetfulness, learning difficulties, difficulty finding words
Group 4 frequent infections, sinusitis, lymph node swellings, joint and limb pains, nerve and soft tissue pains, numbness or tingling, allergies
Group 5 tinnitus, hearing loss, sudden hearing loss, giddiness, impaired balance, visual disturbances, eye inflammation, dry eyes
Group 6 tachycardia, episodic hypertension, collapse
Group 7 other symptoms: hormonal disturbances, thyroid disease, night sweats, frequent urge to urinate, weight increase, nausea, loss of appetite, nose bleeds, skin complaints, tumors, diabetes

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Specific Absorption Rate (SAR) in the head of Tablet user's

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Abstract—**Wireless communication devices such as tablets are increasing and developing rapidly. The effects of the electromagnetic (EM) waves in the human body from the wireless communication devices have been paid attention. It is well known that the absorption of electromagnetic waves on the human head for a certain period of time may lead to health problems such as headaches, or even worse, significantly increased risk of brain cancer. In this paper, the Specific Absorption Rate (SAR) in the head of tablet user's is simulated for three different head models and compared with available international recommendations. The models used are the Specific Anthropomorphic Mannequin (SAM) and two realistic models of human head (a 34 years old adult and a 6 years old child). The simulations were performed using the finite difference time domain (FDTD) method and the frequency used to feed the antenna was 2.45 GHz. All the results are below the safety recommendations set up by the International Commission Non-Ionizing Radiation Protection (ICNIRP) and the Federal Communications Committee (FCC). Among the heterogeneous models, the highest peak spatial Specific Absorption Rate (psSAR) values are estimated for the children. For 1 g psSAR the child heterogeneous model shows highest value in comparison to the SAM model.**

Keywords—Tablets; Specific absorption rate; Specific anthropomorphic mannequin; Finite-difference time-domain method

I. INTRODUCTION

SAR evaluations in the human body from a tablet computer is increasing in recent year. A substantial concern has risen regarding the possible adverse effects on human health [1]-[2] due to the user's electromagnetic (EM) energy absorption for long periods of time. Several safety standards have been defined [3]–[5] in order to prevent harmful effects in human beings exposed to non-ionizing radiation (NIR). The Specific Absorption Rate (SAR) is a unit to indicate the amount of power absorbed per unit mass of human biological tissue when exposed to electromagnetic radiation. The SAR is defined using the following equation (1):

$$SAR = \int \frac{\sigma\,(r)\,|E\,(r)|^2}{\rho\,(r)}\,d(r) \qquad (1)$$

where σ is the electrical equivalent conductivity of the sample (S/m), ρ is the density of the sample (Kg/m³), and *E* is the RMS electric-field (V/m).

The exposure limit recommended by ICNIRP and FCC are psSAR lower than 2 W/Kg for any 10 g of tissue or psSAR lower than 1.6 W/Kg for any 1 g of tissue respectively.

This paper will focus on the impact of the radiation on the SAR values produced by Tablet devices in realistic adults and children head models and in the SAM Phantom. The simulations are based on the Finite Difference Time Domain (FDTD) method. The commercial software SEMCAD-X [6] was used for the SAR simulations.

The paper is organized as follows. Section II shows the modeling and the device used. In section III the relevant international recommendations limits for the SAR are described. Section IV shows the computational resources. Simulated results are discussed in section V and the in section VI the conclusions are presented.

II. MODELING

A. Tablet case model

Fig. 1 shows the tablet model with 134.7 × 200.1 × 9.34 mm³ size. A popular tablet shape model was selected from Grabcad database [7] and then imported into the SEMCAD X software where it was adapted and the antenna was included. The relevant case parameters are included in Table I.

B. Antenna model

Fig. 2 shows some details of the Planar Inverted F antenna (PIFA). A suitable antenna from the Antenna Magus Software database [8] was selected and imported into the SEMCAD X software. After this, its dimensions and shape were adjusted to fit the requirements of this project. The antenna was designed to operate in the 2.45 GHz Wi-Fi communication band and tested, showing good performance in the mid-band (see Table II). It was positioned in the upper right side of the tablet. The relevant antenna parameters are included in Table II.

C. SAM phantom

The SAM phantom is an available [9] adult human head model made of plastic shell, with ear spacers in two sides of the head and a homogeneous liquid inside the shell, elaborated with electrical parameters close to the average head tissues dielectric parameters. Table III contains the dielectric properties of the SAM phantom [9]. The SAM phantom with the Tablet is shown on Fig. 3.

D. *Adult and children head models*

Two available [10] realistic head models were used in these simulations. They are heterogeneous and reproduce approximately the human head tissue morphology. These models were obtained from magnetic resonance imaging (MRI) and are available at the Virtual Family [10].

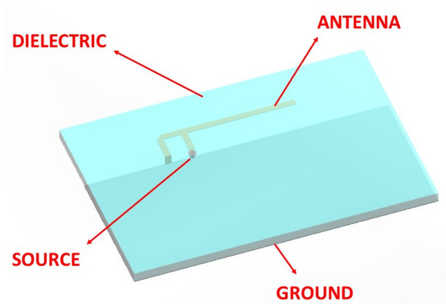
These models are shown on Fig. 4. The first one is a 34 years old adult man (DUKE) and the second is a 6 years old boy (THELONIOUS). The different tissue dielectric parameters used in these simulations were obtained from [11] and are included in Table IV.

(a) (b)

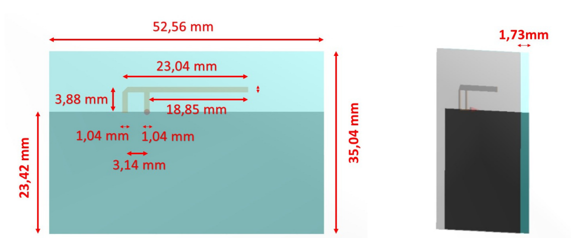
Fig. 1. Tablet configurations: (a) Tablet (front view); (b) Tablet (side view).

TABLE I. Dielectric Properties of the Tablet @ 2.45GHz.

	σ [S/m]	ε_r
Screen	0.0001	2.3
Case	0.0001	2.3



(a)



(b) (c)

Fig 2. Antenna (PIFA) configurations: (a) Antenna PIFA (structure); (b) Antenna PIFA (front view); (c) Antenna PIFA (side view).

TABLE II. Dielectric Properties and Measured Characteristics of the Antenna PIFA @ 2.45GHz.

Dielectric Properties		***Measured Characteristics***	
σ [S/m]	ε_r	*S11 [dB] for 2.45 GHz*	*Zo [Ω]*
0.0001	2	-36.8	50

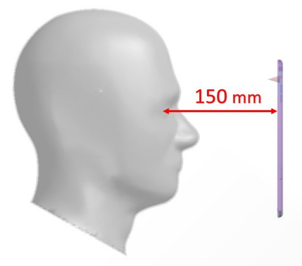
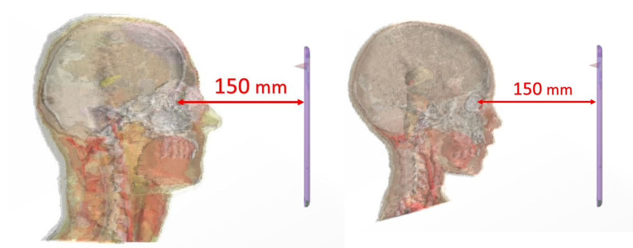


Fig 3. SAM phantom (homogeneous model) with Tablet.

TABLE III. Dielectric Properties of the SAM Phantom following the IEEE 1528 Recommended Practice @ 2.45 GHz

Material	*σ [S/m]*	ε_r
SAM shell	0.0016	5
SAM liquid	1.8	39.2



(a) 34 years old adult man (DUKE)

(b) 6 years old child (THELONIOUS)

Fig. 4. Heterogeneous models with Tablet.

TABLE IV. Dielectric Properties of the Heterogeneous Models Tissues @ 2.45 GHz.

Tissue	ε_r	*σ [S/m]*
Fat	0.104	5.280
Bone	0.394	11.381
Grey matter	1.807	48.911
White matter	1.215	36.167
Liquid Brain	66.243	3.457
Muscle	52.729	1.738
Aqueous Humor	68.208	2.478
Skin	38.007	1.464
Crystalline	44.625	1.504
Sclera	52.628	2.033
Vitreous Humor	68.208	2.478
Cerebellum	30.145	1.088
Nerve	30.145	1.088

III. *International Recommendations*

Some international organizations recommend the evaluations and exposure limits to electromagnetic fields generated by wireless devices near the human body (e.g., [3-5]). Table V shows some recommended exposure limits.

The IEEE 1528.2003 standard [9] uses a simplified human head model to estimate the average peak spatial SAR value generated by communication devices in the range from 300 MHz to 3 GHz. It is designed to provide a conservative estimate of the maximum average values of SAR during normal use of these devices. A model for the human anatomy (SAM phantom) was developed to evaluate the exposure in the near field produced by wireless devices.

The IEC 62209-1 and IEC 62209-2 standards [12] deal with the assessment of exposure to electromagnetic fields generated by wireless devices near the human body in the frequency range 30 MHz to 6 GHz. These are applicable to any devices operating at distances up to 200 mm away from the body, e.g., when it is near the face or any other body region.

TABLE V. Standard and Recommendations. Limits for General Population/Uncontrolled Exposure

	ICNIRP [5]	IEEE [3]	IEEE [14]	FCC [4]
Last Revision	1998	2005	2004	2001
Head and Trunk SAR (W/kg)	2	2	1.6	1.6
Tissue mass (g)	10	10	1	1
Exposure time (min)	6	6	30	30

IV. *Computational Resources*

All the simulations in this work were performed using a computer Intel Core i5 3470 at 3.4 GHz equipped with 32 GB of RAM, NVidia Tesla C1060 GPU card, and Windows 7 Professional x64 operating system, available in the communications laboratory (LACOM) of the Federal University of Rio Grande do Sul. The finite difference time domain-FDTD method was used to simulate different scenarios for the models and to estimate the SAR.

V. *Results and Discussion*

A tablet, including the antenna and the box, was simulated at 2.45 GHz assuming 30 mW normalized radiated power and the distance between the eye lens of the head models and the tablet was 150 mm. The SAR in the head models is estimated in each situation of exposure.

In Table VI the absorbed power percentages are shown in each case. The estimation with the SAM phantom shows that 5,5 % of the energy was absorbed by this model. For the Adult Head model 4,71 % of the energy was absorbed and for the Children Head model 3,97 %. In the Fig. 7 the radiation pattern as well as the SAR in a sagittal slice are shown.

The 10 g and 1 g psSAR were estimated and are shown in Table VII and Fig. 5-6. All the results simulated are below the FCC psSAR limit [13] of 1.6 W/Kg in each 1 g of tissue and the ICNIRP psSAR limit of 2 W/Kg in each 10 g of tissue.

In the simulations for 1 g of tissue, the highest psSAR value is in the children head model (Fig. 5).

In the simulations for 10 g of tissue, the highest psSAR value is in the SAM Phantom, and in the heterogeneous models, the highest psSAR value is in the children head model (Fig. 6).

TABLE VI. Absorbed Power Percentage

SAM Phantom	Adult Head (DUKE)	Children Head (THELONIOUS)
5.50 %	4.71%	3.97%

TABLE VII. psSAR OVER 1 g AND 10 g [W/kg]

SAM Phantom		Adult Head (DUKE)		Children Head (THELONIOUS)	
SAR 10 g	***SAR 1 g***	***SAR 10 g***	***SAR 1 g***	***SAR 10 g***	***SAR 1 g***
0.0062	0.0122	0.0047	0.0114	0.0056	0.0132

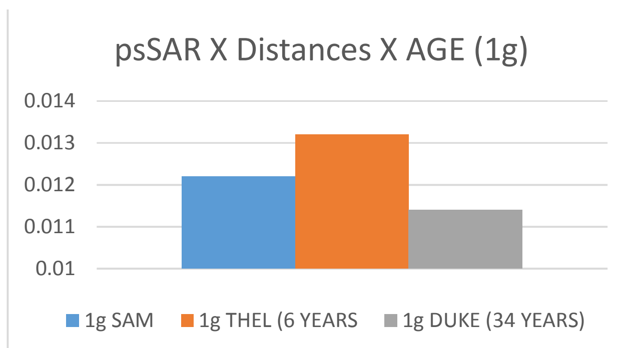


Fig. 5. psSAR 1 g

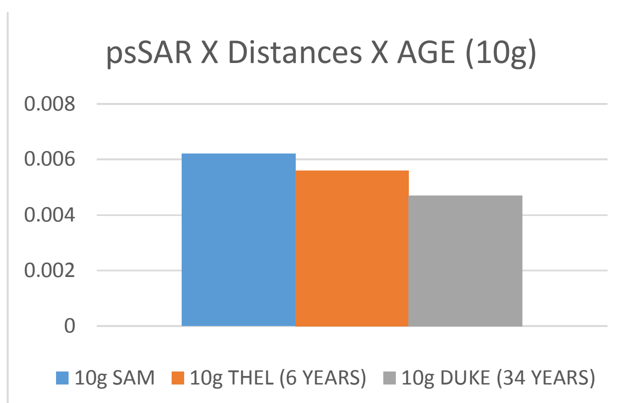


Fig. 6. psSAR 10 g

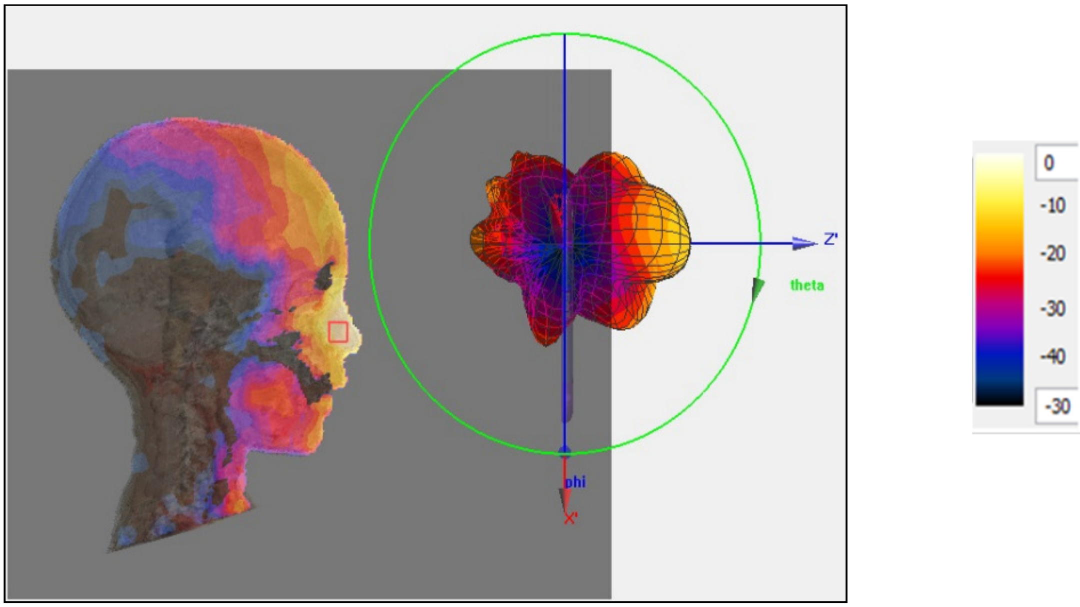


Fig. 7. Radiation pattern normalized to 0.0132 W/g = 0 dB, with a 30 dB color scale, and SAR averaged over 1g cube of tissue.

VI. CONCLUSION

The 1 g and 10 g of tissue psSAR produced in the head of Tablet user's was simulated when a PIFA antenna was employed in three different head models.

The homogeneous SAM phantom head model did not present the higher levels of the 1g psSAR. Therefore, according to these simulations, in 1g volume the SAM is not conservative. It is recommended that the existing mobile devices certification process should be complemented:

- … with an FDTD computer simulation process,
- … using anatomically based models, including those representatives of the children,
- … measuring the SAR, averaged over smaller volumes,
- …and in different tissues.

Then certification should be approved only if all tests result in psSAR below the recommended limits.

The psSAR simulations in heterogeneous models (adult and child) show higher levels in the children model. The possible reasons for the higher SAR estimated in the child head model compared with adult model can be due to different reasons (e.g. thinner skull, higher dielectric parameters, smaller dimensions, etc.).

It is very important to remark that the recommendations and the standards usually adopted in different countries only consider the health effects of short time of exposure. Adults, adolescents and children may use these devices for many hours a day, many days a week and many weeks each year. Then these exposures should be reduced in order to reduce the health risks and the standards should be revised again since the last review was many years ago.

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Cancer epidemiology update, following the 2011 IARC evaluation of radiofrequency electromagnetic fields (Monograph 102)☆

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Mobile phones

ABSTRACT

Epidemiology studies (case-control, cohort, time trend and case studies) published since the International Agency for Research on Cancer (IARC) 2011 categorization of radiofrequency radiation (RFR) from mobile phones and other wireless devices as a possible human carcinogen (Group 2B) are reviewed and summarized. Glioma is an important human cancer found to be associated with RFR in 9 case-control studies conducted in Sweden and France, as well as in some other countries. Increasing glioma incidence trends have been reported in the UK and other countries. Non-malignant endpoints linked include acoustic neuroma (vestibular Schwannoma) and meningioma. Because they allow more detailed consideration of exposure, case-control studies can be superior to cohort studies or other methods in evaluating potential risks for brain cancer. When considered with recent animal experimental evidence, the recent epidemiological studies strengthen and support the conclusion that RFR should be categorized as carcinogenic to humans (IARC Group 1). Opportunistic epidemiological studies are proposed that can be carried out through cross-sectional analyses of high, medium, and low mobile phone users with respect to hearing, vision, memory, reaction time, and other indicators that can easily be assessed through standardized computer-based tests. As exposure data are not uniformly available, billing records should be used whenever available to corroborate reported exposures.

1. Introduction

With rapidly increasing applications for wireless devices targeting populations of all ages, exposures to the associated radiofrequency radiation (RFR) are increasing in number and diversity. Radiation sources include communications devices such as mobile (cell) or cordless phones, laptops and tablets, baby monitors, wearable devices and associated infrastructure (e.g. routers, antennae on towers, and distributed antennae systems (DAS) that can employ directional couplers or wireless amplifiers to enhance accessibility). Thus, the technology entails direct and growing personal exposures to an expanding array of wireless transmitting devices (WTDs).

In 2011, a Working Group of the World Health Organization's International Agency for Research on Cancer (IARC) classified RFR as a possible human carcinogen (Group 2B) (IARC, 2013). In this paper we review the human epidemiology and some other relevant studies published since the IARC Working Group meeting.

1.1. Wireless phone types

The principal sources of exposure of humans to RFR are cell and cordless phones. The radiated power and technologies for cell phones have evolved over the years, as summarized in Table 1 (Hardell and Carlberg, 2015).

2. Case-control studies; glioma

Aydin et al. (2011) reported the results of CEFALO, a multicenter

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Brief Communication

Numerical Evaluation of Human Exposure to WiMax Patch Antenna in Tablet or Laptop

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The use of wireless communication devices, such as tablets or laptops, is increasing among children. Only a few studies assess specific energy absorption rate (SAR) due to exposure from wireless-enabled tablets and laptops, in particular with Worldwide Interoperability for Microwave Access (WiMax) technology. This paper reports the estimation of the interaction between an E-shaped patch antenna (3.5 GHz) and human models, by means of finite-difference time-domain (FDTD) method. Specifically, four different human models (young adult male, young adult female, pre-teenager female, male child) in different exposure conditions (antenna at different distances from the human model, in different positions, and orientations) were considered and whole-body, 10 and 1 g local SAR and magnetic field value (Bmax) were evaluated. From our results, in some worst-case scenarios involving male and female children's exposure, the maximum radiofrequency energy absorption (hot spots) is located in more sensitive organs such as eye, genitals, and breast. Bioelectromagnetics. 39:414–422, 2018. © 2018 Wiley Periodicals, Inc.

Keywords: FDTD; RF exposure; SAR; virtual population; WiMax; wireless communication device

INTRODUCTION

The use of wireless communication devices, such as tablets or laptops, is increasing among children. Worldwide Interoperability for Microwave Access (WiMax) is a communication system based on IEEE 802.16 [2004], belonging to fourth generation (4G) technology with well-known Long-term Evolution (LTE). Mobile WiMAX technology is an ideal means for a new generation of mobile Web applications since it allows mobile client machines to be connected to the Internet. The effects of electromagnetic (EM) radiation in the human body from communication devices have increasingly been taken into consideration in recent years. Specific absorption rate (SAR) is a standard dosimetric parameter [ICNIRP, 1998] for exposure to EM fields between 100 kHz and 10 GHz. SAR quantifies the absorbed energy providing whole-body heat stress and excessive localized tissue heating. Furthermore, SAR is proportional to the square of the internal electric field.

The International Commission on Non-Ionizing Radiation Protection (ICNIRP) has defined some reference levels from basic restrictions on induced whole-body-averaged SAR and peak 10 g spatial-averaged SAR [ICNIRP, 1998] to avoid potentially adverse health effects of EM fields in radiofrequency (RF) range (up to 300 GHz). The ICNIRP guidelines have been adopted by most countries. Generally, long-term EM field exposure is not considered in these guidelines, since consistent induction of cancer is not established. For this reason, ICNIRP guidelines consider only short-term, immediate health effects, such as elevated tissue temperatures resulting from absorption of energy during exposure to EM fields. These effects are produced above a certain threshold and this allows for setting some exposure limits for

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Conflict of interest: None.

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Wi-Fi is an important threat to human health☆

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ABSTRACT

Repeated Wi-Fi studies show that Wi-Fi causes oxidative stress, sperm/testicular damage, neuropsychiatric effects including EEG changes, apoptosis, cellular DNA damage, endocrine changes, and calcium overload. Each of these effects are also caused by exposures to other microwave frequency EMFs, with each such effect being documented in from 10 to 16 reviews. Therefore, each of these seven EMF effects are established effects of Wi-Fi and of other microwave frequency EMFs. Each of these seven is also produced by downstream effects of the main action of such EMFs, voltage-gated calcium channel (VGCC) activation. While VGCC activation via EMF interaction with the VGCC voltage sensor seems to be the predominant mechanism of action of EMFs, other mechanisms appear to have minor roles. Minor roles include activation of other voltage-gated ion channels, calcium cyclotron resonance and the geomagnetic magnetoreception mechanism. Five properties of non-thermal EMF effects are discussed. These are that pulsed EMFs are, in most cases, more active than are non-pulsed EMFs; artificial EMFs are polarized and such polarized EMFs are much more active than non-polarized EMFs; dose-response curves are non-linear and non-monotone; EMF effects are often cumulative; and EMFs may impact young people more than adults. These general findings and data presented earlier on Wi-Fi effects were used to assess the Foster and Moulder (F&M) review of Wi-Fi. The F&M study claimed that there were seven important studies of Wi-Fi that each showed no effect. However, none of these were Wi-Fi studies, with each differing from genuine Wi-Fi in three distinct ways. F&M could, at most conclude that there was no statistically significant evidence of an effect. The tiny numbers studied in each of these seven F&M-linked studies show that each of them lack power to make any substantive conclusions. In conclusion, there are seven repeatedly found Wi-Fi effects which have also been shown to be caused by other similar EMF exposures. Each of the seven should be considered, therefore, as established effects of Wi-Fi.

1. Introduction

Wi-Fi (also known as WiFi or WLAN) is a wireless network involving at least one Wi-Fi antenna connected to the internet and a series of computers, laptops and/or other wireless devices communicating wirelessly with the Wi-Fi antenna. In this way, each such wireless communication device can communicate wirelessly with the internet. All the studies reviewed here were of Wi-Fi using the 2.4 GHz band, although there is also a 5 GHz band reserved for possible Wi-Fi use.

Telecommunications industry-linked individuals and groups have claimed that there are no and cannot possibly be any health impacts of Wi-Fi (Foster and Moulder, 2013; Berezow and Bloom, 2017). However with Wi-Fi exposures becoming more and more common and with many of our exposures being without our consent, there is much concern about possible Wi-Fi health effects. This paper is not focused on anecdotal reports but rather on 23 controlled, scientific studies of such health-related effects in animals, cells including human cells in culture and in human beings (Table 1).

Each of the effects reported above in from 2 to 11 studies, have an extensive literature for their occurrence in response to various other non-thermal microwave frequency EMFs, discussed in detail below. These include (see Table 1) findings that Wi-Fi exposures produce impacts on the testis leading to lowered male fertility; oxidative stress; apoptosis (a process that has an important causal role in neurodegenerative disease); cellular DNA damage (a process causing cancer and germ line mutations); neuropsychiatric changes including EEG changes; hormonal changes.

The discussion here focuses on those Wi-Fi effects which have been found by multiple Wi-Fi studies and have been previously confirmed by non-thermal exposures to other microwave frequency EMFs. The 1971/72 U.S. Office of Naval Medical Research study (Glaser, 1971) reported the following changes related to testis or sperm: 1. Decreased testosterone leading to lowered testis size. 2. Histological changes in testicular epithelial structure. 3. Gross testicular histological changes. 4.

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Table 1
Summary of health impacts of Wi-Fi EMF exposures.

Citation(s)	Health Effects
Atasoy et al. (2013); Özorak et al. (2013); Aynali et al. (2013); Çiftçi et al. (2015); Tök et al. (2014); Çiğ and Nazıroğlu (2015); Ghazizadeh and Nazıroğlu (2014); Yüksel et al. (2016); Othman et al. (2017a, 2017b); Topsakal et al. (2017)	Oxidative stress, in some studies effects lowered by antioxidants
Atasoy et al. (2013); Shokri et al. (2015); Dasdag et al. (2015); Avendaño et al. (2012); Yildiring et al. (2015); Özorak et al. (2013); Oni et al. (2011); Akdag et al. (2016)	Sperm/testicular damage, male infertility
Papageorgiou et al. (2011); Maganioti et al. (2010); Othman et al. (2017a, 2017b); Hassanshahi et al. (2017)	Neuropsychiatric changes including EEG; prenatal Wi-Fi leads to post-natal neural development, increased cholinesterase; decreased special learning; Wi-Fi led to greatly lowered ability to distinguish familiar from novel objects, changes in GABA and cholinergic transmission
Shokri et al. (2015); Dasdag et al. (2015); Çiğ and Nazıroğlu (2015); Topsakal et al. (2017)	Apoptosis (programmed cell death), elevated apoptotic markers
Avendaño et al. (2012); Atasoy et al. (2013); Akdag et al. (2016)	Cellular DNA damage
Saili et al. (2015); Yüksel et al. (2016); Topsakal et al. (2017)	Endocrine changes incl.: Catecholamines, pancreatic endocrine dysfunction, prolactin, progesterone and estrogen
Çiğ and Nazıroğlu (2015); Ghazizadeh and Nazıroğlu (2014)	Calcium overload
Aynali et al. (2013)	Melatonin lowering; sleep disruption
Othman et al. (2017a)	MicroRNA expression (brain)
Othman et al. (2017a)	Abnormal postnatal development
Çiftçi et al. (2015)	Disrupts development of teeth
Saili et al. (2015)	Cardiac changes, blood pressure disruption; erythrocyte damage
Lee et al. (2014)	Growth stimulation of adipose stem cells (role in obesity?)

Decreased spermatogenesis. Glaser (1971) also reported a total of 35 neurological/neuropsychiatric effects of non-thermal EMF exposures, including 9 central nervous system effects, 4 autonomic system effects, 17 psychological disorders, 4 behavioral changes and EEG changes. It also reported 7 types of chromosomal aberrations several of which are known to be caused by chromosomal double stranded DNA breaks, 8 types of endocrine changes, and cell death (what we now call apoptosis). Glaser (1971) also provided over 1000 different citations each reporting various types of non-thermal microwave frequency EMF effects. Consequently, the existence of 5 types of Wi-Fi effects, each supported by multiple Wi-Fi studies were already well-supported *as general non-thermal EMF effects* back in 1971, 47 years ago: effects on the testis and sperm production, neurological/neuropsychiatric effects, endocrine effects, attacks on cellular DNA and increased apoptosis/cell death.

The 146 page review published by Tolgskaya and Gordon (1973) found that in studies of histological changes in rodents, the three most sensitive organs in the body to non-thermal microwave EMFs were the nervous system (including the brain), followed closely by the heart and the testis. They also reported changes in neuroendocrine tissues and increased cell death in multiple tissues. Thus those pre-1973 rodent studies already showed that other EMFs caused 4 of the repeated, recently documented Wi-Fi effects: changes in testis structure/function, neurological effects, increased cell death (possibly via apoptosis) and endocrine effects. Findings from our longer list of EMF reviews of non-thermal effects are summarized in Table 2.

Each of the 7 Wi-Fi effects found in 2–11 studies (Table 1), have also been found to be caused by other microwave frequency EMFs, in a much larger literature (Table 2). From 10 to 16 reviews extensively document each of these seven effects as general microwave frequency effects (Table 2). These are, therefore, general effects produced by such EMFs. Each of these 7 repeatedly found Wi-Fi effects should, therefore, be considered established Wi-Fi effects. The author is not aware of any genuine Wi-Fi studies on these 7 effects that reported no statistically significant evidence of effect.

Each of these 7 is very serious: Oxidative stress has causal roles in most chronic human diseases; cellular DNA damage can cause cancer, thus producing a partial explanation for EMF cancer causation; because such DNA damage occurs in sperm cells (Atasoy et al., 2013; Avendaño et al., 2012; Akdag et al., 2016; Adams et al., 2014; Liu et al., 2014; Asghari et al., 2016), such damage is highly likely to produce mutations that impact future generations; calcium overload is highly likely to be the cause of each of these various other effects, as discussed below; apoptosis has central roles in neurodegenerative diseases; the neuropsychiatric effects are almost certainly caused by the impact of EMFs on brain structure which is extensively documented and, in my opinion, produces many impacts (Pall, 2016b). A recent meta-analysis shows major lowering of sperm counts and sperm quality in many countries around the world, with declines of over 50% in all advanced technology countries (Levine et al., 2017). The senior author of this study suggested that this effect alone may lead to human extinction (No authors listed, 2017). Given the major impact of EMF exposures on sperm count and quality in human and in animal studies, the pattern of evidence on male fertility is very worrying.

One thing needs to be clarified, here, however. In the two studies on calcium overload following Wi-Fi exposure, such overload was measured a substantial time period following exposure. Overload was shown to be caused, to a substantial effect, by increased TRPV1 receptor activity (Çiğ and Nazıroğlu, 2015; Ghazizadeh and Nazıroğlu, 2014). The TRPV1 receptor is known to be activated by oxidative stress. It is my view, discussed in detail below, that there is a central mechanism that acts to produce excessive intracellular calcium immediately following EMF exposure and that the oxidative stress/TRPV1 activation is secondary.

We have then, major impacts of non-thermal EMF exposures on both of the most important intercellular regulatory systems in the body, the nervous system and the endocrine systems. We have major impacts on what may be the most important intracellular regulatory system, the calcium regulatory system. And we also have non-thermal EMFs attacking the DNA of our cells, putting our biological inheritance at great risk. As living organisms, EMFs attack each of the most important functions that go to the heart of our human complexities.

Despite all of these clear and important, non-thermal effects, and the fact that there was substantial evidence for many of them already known before 1973, our current U.S. and international safety guidelines are still based on considering only thermal effects.

2. Wi-Fi and other wireless communication EMFs are pulsed, leading to larger biological impacts; These EMFs are also polarized, also producing larger effects; Dose response curves are often both non-linear and non-monotone

There are three patterns of EMF action, each of which is very important and each of which is almost universally ignored by the

Table 2
Reviews of Non-thermal Effects of Microwave Frequency EMFs Similar to Those Found in Multiple Wi-Fi Studies.

Non-thermal effects	Citations
Cellular DNA damage	Glaser (1971); Yakymenko et al. (1999); Aitken and De Iuliis (2007); Hardell and Sage (2008); Hazout et al. (2008); Phillips et al. (2009); Ruediger (2009); Makker et al. (2009); Yakymenko and Sidorik (2010); Batista Napotnik et al. (2010); Yakymenko et al. (2011); Pall (2013, 2015b); Asghari et al. (2016); Pall (2018)
Changes in testis structure, lowered sperm count/ quality	Glaser (1971); Tolgskaya and Gordon (1973); Aitken and De Iuliis (2007); Hazout et al. (2008); Desai et al. (2009); Gye and Park (2012); Nazıroğlu et al. (2013); Carpenter (2013); Adams et al. (2014); Liu et al. (2014); Houston et al. (2016); La Vignera et al. (2012); Makker et al. (2009)
Neurological/neuropsychiatric effects	Glaser (1971); Tolgskaya and Gordon (1973); Raines (1981); Lai (1994); Grigor'ev (1996); Hardell and Sage (2008); Makker et al. (2009); Khurana et al. (2010); Levitt and Lai (2010); Consales et al. (2012); Carpenter (2013); Pall (2016b); Belyaev et al. (2016); Sangün et al. (2016); Kaplan et al. (2016)
Apoptosis/cell death	Glaser (1971); Tolgskaya and Gordon (1973); Raines (1981); Yakymenko et al. (1999); Batista Napotnik et al. (2010); Yakymenko and Sidorik (2010); Pall (2013, 2016b); Asghari et al. (2016); Sangün et al. (2016)
Calcium overload	Adey (1981, 1988); Walleczek (1992); Yakymenko et al. (1999); Gye and Park (2012); Pall (2013, 2015a, 2015b, 2016a, 2016b)); Asghari et al. (2016)
Endocrine effects	Glaser (1971); Tolgskaya and Gordon (1973); Raines (1981); Hardell and Sage (2008); Gye and Park (2012); Hardell and Sage (2008); Makker et al. (2009); Pall (2015b); Sangün et al. (2016); Asghari et al. (2016)
Oxidative stress, free radical damage	Raines (1981); Houston et al. (2016); Hardell and Sage (2008); Hazout et al. (2008); Desai et al. (2009); Yakymenko and Sidorik (2010); Yakymenko et al. (2011); Consales et al. (2012); La Vignera et al. (2012); Nazıroğlu et al. (2013); Yakymenko et al. (2015); Pall (2013, 2018); Dasdag and Akdag (2016); Wang and Zhang (2017)

telecommunications industry and industry-linked organizations. The most extensively reviewed of these is that pulsed EMFs are usually much more biologically active than are non-pulsed (also known as continuous wave) EMFs of identical frequency and similar average intensity (Osipov, 1965; Pollack and Healer, 1967; Creighton et al., 1987; Grigor'ev, 1996; Belyaev, 2005, 2015; Markov, 2007; Van Boxem et al., 2014; Pall, 2015b; Panagopoulos et al., 2015b). This pattern of action is particularly important because all wireless communication devices, including Wi-Fi (Panagopoulos et al., 2015b; Maret, 2015) communicate via pulsations and are likely to be particularly dangerous as consequence of this. Panagopoulos et al., 2015b have argued that the more pulsed they are, the more damaging EMFs will be and while this may still be questioned, it may well be a roughly applicable generalization.

It is also true that artificial EMFs are polarized and this makes artificial EMFs particularly dangerous (Belyaev, 2005, 2015; Panagopoulos et al., 2015a). Polarized EMFs put much larger forces of electrically charged chemical groups than do non-polarized EMFs (Panagopoulos et al., 2015a), an observation that is relevant to the main mechanism of EMF action in living cells discussed below.

It has often been found that there are windows of exposure where specific intensity ranges produce maximum biological effects, which drop off going to both lower or higher intensities (Belyaev, 2005, 2015; Pall, 2015b). It can be seen from this that dose-response curves are often both non-linear and non-monotone whereas industry linked groups often assume a linear and therefore monotone dose-response curve.

3. EMF effects are often cumulative and irreversible

One question that has been raised about the effects of these low-intensity EMFs producing biological effects is are they cumulative? I am aware of three different types of evidence for cumulative effects. Three of the human occupational exposure studies from the 1970's reviewed in Raines (1981), showed that effects increased substantially with increasing time of exposure to a particular type and intensity of EMF.

The impacts of such EMFs on animal brains were reviewed in Tolgskaya and Gordon (1973) and discussed in Pall (2016b). Initially exposures over period of 1–2 months produced relatively modest changes in structure of the brain and the neurons and when exposures ceased, most of the structural changes disappeared – that is the changes were largely reversible. However more months of exposure produced much more severe impacts on brain and neuronal structure and these were irreversible (Tolgskaya and Gordon, 1973; Pall, 2016b).

Magras and Xenos (1997) put pairs of young mice into cages on the ground at two locations each with somewhat different exposures within an antenna park. The exposure levels at both sites were well within safety guidelines, so if the safety guidelines have any biological relevance, there should have been no apparent effects. It takes about 30 days for mice to go through gestation. At the higher level exposure, the pairs produced one litter of lower than normal size, and a second litter with lowered numbers of progeny; after that they were completely sterile or had extremely low fertility (Magras and Xenos, 1997). At the other site, the mating pairs produced four litters, with decreasing numbers of progeny over time followed by complete sterility. In both groups, the mating and possible subsequent gestatation for the fifth possible litter were performed under conditions of no EMF exposure, but the fertility effects were not reversed; therefore fertility effects may become irreversible, suggesting a similar pattern to the brain related effects of EMFs. It should be noted that Özorak el al (2013) showed that Wi-Fi exposure impacted animal reproduction and that (Atasoy et al., 2013; Shokri et al., 2015; Dasdag et al., 2015; Avendaño et al., 2012; Yildiring et al., 2015; Oni et al., 2011; Akdag et al., 2016) suggest this as well from the Wi-Fi impacts on testis structure and sperm production.

Mutation accumulation produced by cellular DNA damage is likely to be both cumulative and irreversible, as well, because later mutations are highly unlikely to reverse previously occurring mutations.

We have therefore reason to think that such effects as brain damage to animal brains, neuropsychiatric effects in humans, reproductive dysfunction in mice and mutational effects, are each cumulative. Those same effects may be completely or largely irreversible. One thing that this should tell us is that the short-term Wi-Fi studies shown in Table 1 may *greatly underestimate* the damage Wi-Fi may do over much longer time periods. Given the fact that Wi-Fi has been placed in most schools, hotels, restaurants, coffee shops, commercial aircraft and airports as well as in many homes and that Wi-Fi hot spots are becoming increasingly common in cities around the world, we should expect massive cumulative Wi-Fi effects in many people. A second tentative inference is that false assurances of safety on the part of industry are likely to lead to much more severe effects on people exposed to Wi-Fi or other EMFs; rather than leading them to protect themselves or their children by avoiding exposures or demanding that others stop non-voluntary exposures, they are likely to avoid protective changes or be prevented from doing such protective changes. A third inference is that these effects may be among the more difficult ones for us to attribute to EMF exposure. We are much more aware of effects that occur rapidly than those that take months or years before they become readily apparent.

4. Wi-Fi and other EMFs may be particularly damaging to young people

Most arguments that have been made that microwave frequency EMFs may be much more damaging to young children have centered on the much smaller skulls and skull thickness in young children, increasing the exposure of their brains to EMFs (Gandhi and Kang, 2001; Gandhi et al., 2012). However there are other arguments to be made. EMFs have been shown to be particularly active in producing effects on embryonic stem cells (Lee et al., 2014; Belyaev et al., 2009; Markovà et al., 2010; Czyz et al., 2004; Xu et al., 2016; Bhargav et al., 2015; Odaci et al., 2008; Uchugonova et al., 2008; Wang et al., 2015; Teven et al., 2012). Because such stem cells occur at much higher cell densities in children, with stem cell densities the highest in the fetus and decreasing with increasing age (Belyaev et al., 2009; Markovà et al., 2010), impacts on young children are likely to be much higher than in adults. The decreased DNA repair and increased DNA damage following EMF exposure strongly suggest that young children may be increasingly susceptible to cancer following such exposures (Belyaev et al., 2009; Markovà et al., 2010; Czyz et al., 2004). EMF action on stem cells may also cause young children to be particularly susceptible to disruption of brain development (Xu et al., 2016; Bhargav et al., 2015), something that may be relevant to autism causation. These are all very problematic issues and we cannot rule out the possibility that there are other problematic issues as well. Redmayne and Johansson (2015) reviewed the literature showing that there are age-related effects, such that young people are more sensitive to EMF effects. It follows from these various findings that the placement of Wi-Fi into schools around the country may well be a high level threat to the health of our children as well being a threat to teachers and any very sensitive fetuses teachers may be carrying, as well.

5. How do EMF exposures lead to non-thermal health impacts?

The author found the answer to this question in the already published scientific literature (Pall, 2013). That study showed that in 24 different studies [there are now a total of 26 Pall (2015b)], effects of low-intensity EMFs, including microwave frequency and also extremely low frequency EMFs, static electrical fields and static magnetic fields could be blocked by calcium channel blockers, drugs that are specific for blocking voltage-gated calcium channels (VGCCs). There were 5 different types of calcium channel blockers used in these studies, each thought to be highly specific, each structurally distinct and each binding to a different site on the VGCCs. In studies where multiple effects were studied, all studied effects were blocked or greatly lowered by calcium channel blockers. These studies show that EMFs produce diverse non-thermal effects via VGCC activation Pall (2013, 2014, 2015a, 2015b, 2016a, 2016b)) in many human and animal cells. In plant cells, EMFs activate somewhat similar calcium channels and produce somewhat similar effects on oxidative stress, cellular DNA damage and calcium signaling (Pall, 2016a). Furthermore, many different effects shown to be produced in repeated studies by EMF exposures, including the effects discussed above, can be produced by downstream effects of VGCC activation, via increased [Ca2+]i, as discussed in detail below.

Before leaving this issue, it is important to discuss why the VGCCs are so sensitive to activation by these low-intensity EMFs. The VGCCs each have a voltage sensor which is made up of 4 alpha helixes in the plasma membrane, with each such helix having 5 positive charges on it, for a total of 20 positive charges (Pall, 2015b). These voltage sensor helixes are each called S4 helixes because each is the fourth helix in a distinct multi-helix domain. Each of these voltage sensor charges is within the lipid bilayer part of the plasma membrane. The electrical forces on the voltage sensor are very high for three distinct reasons (Pall, 2015b, 2015a, 2016a). 1. The 20 charges on the voltage sensor make the forces on voltage sensor 20 times higher than the forces on a single charge. 2. Because these charges are within the lipid bilayer section of the membrane where the dielectric constant is about 1/120th of the dielectric constant of the aqueous parts of the cell, the law of physics called Coulomb's law, predicts that the forces on those charges will be approximately 120 times higher than the forces on charges in the aqueous parts of the cell. 3. Because the plasma membrane has a high electrical resistance whereas the aqueous parts of the cell are highly conductive, the electrical gradient across the plasma membrane is estimated to be concentrated about 3000-fold. The combination of these effects means that comparing the forces on the voltage sensor with the forces on singly charged groups in the aqueous parts of the cell, the forces on the voltage sensor are approximately $20 \times 120 \times 3000 = 7.2$ million times higher (Pall, 2015b). The physics predicts, therefore, extraordinarily strong forces activating the VGCCs via the voltage sensor. It follows that the biology tells us that the VGCCs are the main target of the EMFs and the physics tells us why they are the main target. Thus the physics and biology are pointing in the same direction.

There are also additional findings pointing to the voltage sensor as the direct target of the EMFs. In addition to the VGCCs, there are also voltage-gated sodium, potassium and chloride channels, with each of these having a voltage sensor similar to those found in the VGCCs. Lu et al. (2015) reported that voltage gated sodium channels, in addition to the VGCCs were activated by EMFs. Tabor et al. (2014) found that Mauthner cells, specialized neurons with special roles in triggering rapid escape mechanisms in fish, were almost instantaneously activated by electrical pulses, which acted via voltage-gated sodium channel activation to subsequently produce large [Ca2+]i increases. Zhang et al. (2016) reported that in addition to the VGCCs, potassium and chloride channels were each activated by EMFs, although these other voltage-gated ion channels had relatively modest roles compared with the VGCCs in producing biological effects. Each of these three studies, the Lu et al. (2015) study, the Tabor et al. (2014) study and the Zhang et al. (2016) study used specific blockers for these other voltage-gated ion channels to determine their roles. The Tabor et al. (2014) study also used genetic probing to determine the role of the voltage-gated sodium channels. Lu et al. (2015) also used whole cell patch clamp measurements to measure the rapid influx of both sodium and calcium into the cell via the voltage-gated channels following EMF exposure. Sodium influx, particularly in electrically active cells, act in the normal physiology to depolarize the plasma membrane, leading to VGCC activation such that the voltage-gated sodium channels may act primarily via indirect activation of the VGCCs. In summary then, we have evidence that in animal including human cells, seven distinct classes of voltage-gated ion channels are each activated by EMF exposures: From the Pall (2013) review, four classes of voltage-gated ion channels were shown from calcium channel blocker studies, to be activated by EMFs, L-type, T-type, N-type and P/Q –type VGCCs. In this paragraph we have evidence that three other channels are also activated, voltage-gated sodium channels, voltage-gated potassium channels and voltage-gated chloride channels. Furthermore the plant studies strongly suggest that the so called TPC channels, which contain a similar voltage sensor, are activated in plants allowing calcium influx into plants to produce similar EMF-induced responses (Pall, 2016a). One can put those observations together with the powerful findings from the physics, that the electrical forces on the voltage-sensor are stunningly strong, something like 7.2 million times stronger than the forces on the singly charged groups in the aqueous phases of the cell. Now you have a stunningly powerful argument that the voltage sensor is the predominant direct target of the EMFs.

There is one additional finding that should be discussed here. In a study published by Pilla (2012), it was found that pulsed EMFs produced an “instantaneous” increase in calcium/calmodulin-dependent nitric oxide synthesis in cells in culture. What Pilla (2012) showed was that following EMF exposure, the cells in culture, must have produced a large increase in [Ca2 +]i, this in turn produced a large increase in nitric oxide synthesis, the nitric oxide diffused out of the cells and out of the aqueous medium above the cells into the gas phase, where the nitric oxide was detected by a nitric oxide electrode. This entire sequence occurred in less than 5 s. This eliminates almost any conceivable indirect effect, except possibly via plasma membrane depolarization. Therefore that the pulsed EMFs are acting directly on the voltage sensors of the VGCCs and possibly the voltage-gated sodium channels, to produce the [Ca2 +]i increase.

Why is it that the VGCCs, acting via calcium influx, seem to be much more important in producing EMF effects than are the other voltage-gated ion channels? Probably for three reasons: 1. Ca^{2+} ions under resting conditions in cells have about a 10,000-fold concentration gradient driving them into the cell, and over a million-fold electrochemical gradient also driving them into the cell. Because of this, one can have huge calcium influxes upon channel activation. 2. [Ca2 +]i produces many important regulatory effects, such that over activation of those effects can have very large pathophysiological consequences. 3. Sustained elevation of [Ca2+]i produces major cell damage.

6. How can the Wi-Fi effects be produced by EMF triggered VGCC activation?

Can the various effects produced by Wi-Fi and by other microwave frequency EMFs be produced by the downstream effects of VGCC activation? In order to determine that, one needs to consider the various downstream effects of VGCC activation, summarized in Fig. 1 and how these are likely to produce each of the effects of Wi-Fi and other microwave frequency EMFs. Let's consider Fig. 1.

As shown in the top left section of Fig. 1, microwave and lower frequency EMFs act via VGCC activation to produce increases in intracellular calcium [Ca2+]i. All of the downsteam effects of VGCC activation considered in Fig. 1 are produced by elevated (often excessive) [Ca2+]i.

Just to the right of [Ca2+]i in Fig. 1, you will see that elevated [Ca2+]i produced increases in nitric oxide (NO) synthesis. This is because two of the three types of enzymes producing NO are calcium-dependent. There is an NO signaling pathway that goes through increased cGMP and increased protein kinase G activity. Protein kinase G can act by raising the activity of the transcriptional regulatory factor, Nrf2, to produce the therapeutic effects produced by EMF exposures (Pilla, 2013; Pall, 2014; Pall and Levine, 2015).

High levels of NO can bind to heme groups on cytochromes (uppermost section, Fig. 1) inhibiting cytochrome oxidase, the terminal oxidase in the mitochondria, inhibiting ATP synthesis. NO can also inhibit cytochrome P450s involved in steroid hormone synthesis, lowering levels of estrogen, progesterone and testosterone (sex hormones).

The main pathophysiological effects of EMF exposures are produced via excessive calcium signaling (lower left) and the peroxynitrite pathway (lower right). Peroxynitrite levels are elevated because both NO and superoxide are elevated by increased [Ca2+]i with NO and superoxide reacting with each other to form peroxynitrite. Peroxynitrite and its CO_2 adduct, can break down to produce reactive free radicals, hydroxyl radical, carbonate radical and NO_2 radical which produce oxidative stress. These various oxidants act to produce greatly elevated NF-kappaB activity, leading to inflammation. All of this biochemistry and physiology is well-accepted and widely known with a single exception: The role of protein kinase G in raising Nrf2 has only recently been reviewed (Pall and Levine, 2015).

The ways in which these mechanisms can produce each of the seven effects produced by Wi-Fi, as well as other microwave frequency EMFs, are described in Table 3.

It can be seen from Table 3, that there are plausible mechanisms by which each of those seven effects can be produced by VGCC activation via known pathways. Given the complexities of biology, the mechanisms described in Table 3 may, in some cases, be over simplified.

There is one other finding, not related to the Wi-Fi findings, that is included in Table 3. A question that was raised in review of the paper was whether the heat shock stress elevation found following EMF exposure in many studies, could be produced by VGCC activation. As you can see from Table 3, it can be.

7. Other proposed biophysical mechanisms

One question that can be asked is how the VGCC activation mechanism compares with other biophysical models of non-thermal EMF effects. Belyaev (2015) has discussed a number of what he describes as biophysical models which are, therefore considered here. These models are basically theoretical models of how the weak electrical forces of the EMFs can interact with biologically plausible structures to produce non-thermal effects.

The first of these Belyaev considers is Fröhlich's theory. This is where there are “coherent longitudinal vibrations of electrically polar structures.” The mechanism of Fröhlich's theory will not be considered here (the reader is referred to Belyaev, 2015). The author considers this to be a plausible mechanism for possible production of some non-thermal EMF effects. However, there are no specific testable predictions made by the theory that suggest how it could be tested, given the fact that there may be multiple possible targets of the EMFs according to

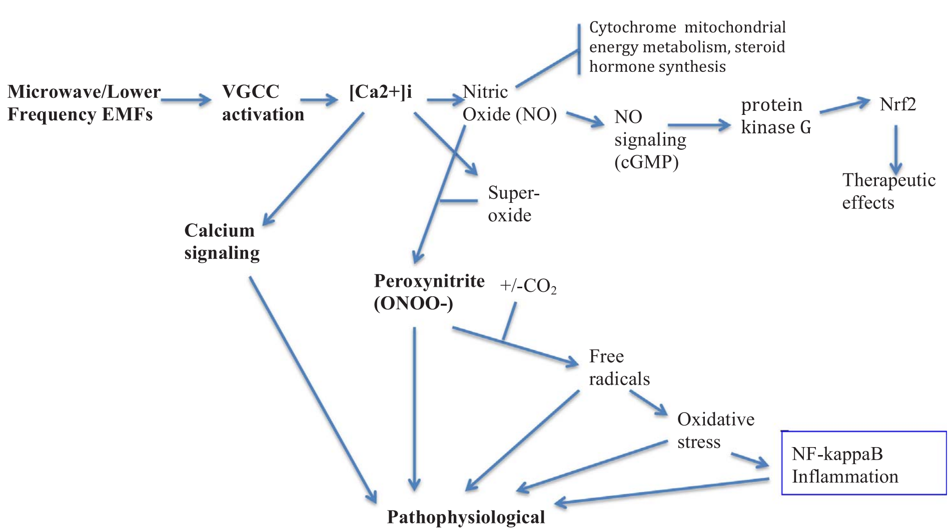

Fig. 1. Various pathways of action by which EMF VGCC activation can produce effects produced by EMF exposure (modified, with permission from Pall, 2015b).

Table 3
How Eight Established Effects of Wi-Fi and Other EMFs Can Be Produced by VGCC Activation.

EMF effect	Probable mechanism(s)
Oxidative stress	Produced by elevated levels of peroxynitrite and the free radical breakdown products of peroxynitrite and its $C0_2$ adduct. Four studies of EMF exposure, cited in Pall (2013) showed that oxidative stress following exposure was associated with major elevation of 3-nitrotyrosine, a marker of peroxynitrite, thus confirming this interpretation. Two other studies each found 3-nitrotyrosine elevation, both following 35 GHz exposures (Sypniewska et al. (2010); Kalns et al., 2000).
Lowered male/female fertility, elevated spontaneous abortion, lowered libido	Both the lowered male fertility and lowered female fertility are associated with and presumably caused by the oxidative stress in the male and female reproductive organs. Spontaneous abortion is often caused by chromosomal mutations, so the germ line mutations may have a causal role. Lowered libido may be caused by lowered estrogen, progesterone and testosterone levels. It seems likely that these explanations may be greatly oversimplified. One mechanism that may be important in lowered fertility is that VGCC activation and consequent high {Ca2+]i levels is known to have a key role in avoiding polyspermy. Consquently, if this if triggered before any fertilization of an egg has occurred, it may prevent any sperm from fertilizing and egg.
Neurological/ neuropsychiatric effects	Of all cells in the body, the neurons have the highest densities of VGCCs, due in part to the VGCC role and [Ca2+]i role in the release of every neurotransmitter in the nervous system. Calcium signaling regulates synaptic structure and function in 5 different ways, each likely to be involved here. Oxidative stress and apoptosis are both thought to have important roles. Lowered sleep and increased fatigue are likely to involve lowered nocturnal melatonin and increased nocturnal norepinephrine.
Apoptosis	Apoptosis can be produced by excessive Ca2+ levels in the mitochondria and by double strand breaks in cellular DNA; it seems likely that both are involved following EMF exposure. A third mechanism for triggering apoptosis, endoplasmic reticulum stress (see bottom row in this Table), may also be involved.
Cellular DNA damage	Cellular DNA damage is produced by the free radical breakdown products of peroxynitrite directly attacking the DNA [see Pall (2018) for discussion].
Changes in non-steroid hormone levels	The release of non-steroid hormones is produced by VGCC activation and [Ca2+]i elevation. The immediate effects of EMF exposures is to increase hormone release and to raise, therefore, hormone levels. However many hormone systems become “exhausted” as a consequence of chronic EMF exposures. The mechanism of exhaustion is still uncertain, but it may involve oxidative stress and inflammation.
Lowered steroid hormone	Steroid hormones are synthesized through the action of cytochrome P450 enzymes; activity of these hormones is inhibited by binding of high levels of nitric oxide (NO) leading to lowered hormone synthesis.
Calcium overload	Produced by excessive activity of the VGCCs; secondary calcium overload is produced by oxidative stress activation of TRPV1, TRPM2 and possibly some other TRP receptors, opening the calcium channel of these receptors.
Heat shock protein induction	There is a large literature showing that excessive [Ca2+]i induces very large increases in heat shock proteins. This is thought to be produced by complex calcium signaling changes involving the endoplasmic reticulum, mitochondria and the cytosol and also involving excessive [Ca2+]i producing increasing protein misfolding (Garbuz, 2017; Park et al., 2014; Krebs et al., 2011). It should be noted that some calcium is essential for proper protein folding in the endoplasmic reticulum such that only excessive calcium leads to misfolding and consequent endoplasmic reticulum stress.

Fröhlich's theory.

A second possible mechanism involves the spin state of radical pairs. When radical pairs are generated from the breakdown of a non-radical molecule, these radical pairs often react back with each other to form another non-radical molecule, not necessarily identical to the original non-radical. What is postulated by this theory is that EMFs can interact with one or both radicals, changing their spin state and greatly lowering their ability to react back with each other, thus generating increased free radicals and therefore increased oxidative stress. The potential strong point of this theory is that it provides an explanation for the oxidative stress found following EMF exposure. However, as noted under oxidative stress in Table 3, there are 6 studies where oxidative stress following EMF exposure was associated with very high levels of 3-nitrotyrosine, a specific marker of peroxynitrite elevation. These studies argue, therefore, that oxidative stress following EMF exposure is produced by peroxynitrite elevation and is not primarily produced by this radical pair mechanism. It follows from this that the proposed radical pair mechanism cannot even explain the properties of oxidative stress production, let alone the various consequences of non-thermal EMF exposure that do not involve oxidative stress. Does that mean that the radical pair mechanism has no possible role in producing non-thermal EMF effects? No, but it does argue there is no evidence for any such role.

A third mechanism discussed in Belyaev (2015) is the electrosoliton theory proposed by Brizhik and colleagues, involving a “self reinforcing solitary wave packet.” Brizhik and her colleagues discussed this in the context of reaching a threshold minimum energy state where both charged molecules and the EMF is in a coherent state, such that charge movement can ratchet from one state to another. This concept shows substantial similarity to what is thought to occur in the activation of the voltage sensor, that is discussed above. There we have four alpha helixes, each designated an S4 helix and with each S4 helix having 5 positive charges, with the 4 S4 helixes together making up the voltage sensor. Most of those positive charges are 3 amino acid residues apart from each other, such that the closest charged residues stick out from the helix pretty much on the same side of the helix. Three of those positive charges are electrostatically attracted to negative residues on other helixes thought to be in fixed positions. What is thought to happen in activation is that there a ratcheting of the S4 helixes toward the extracellular space, ratcheting such that the negative charges are now bound to a positive charge 3 residues away from the one that was previously bound. The ratcheting also produces some turning of the S4 helix. This needs to occur several times on each of the four S4 helixes to open the channel and allow calcium ions to flow. While I don’t completely understand the Brizhik electrosoliton model, it may well be relevant to our understanding the VGCC activation, because the mechanism of the voltage sensor is similar to what Brizhik and her colleagues propose to occur in the electrosoliton model. Both the electrosoliton model and the voltage sensor activation mechanism involve both charge movements and ratcheting. In order to test these biophysical models one needs to have a specific mechanism where it may apply and where such tests can be done. In the case of the voltage sensor of the VGCCs, these tests have already been done.

These models are basically theoretical models of how the weak electrical forces of the EMFs can interact with biologically plausible structures to produce non-thermal effects. Their theoretical support is their strong point. They are weak, however, in providing any compelling evidence that they have causal roles in producing non-thermal changes in cells in culture or in whole animal (or human) studies. They are also weak because they do not provide stated explanations for the range of EMF effects that have been documented.

Belyaev (2015) discusses microwave hearing in this context. He discusses the findings showing that people can hear microwave fields that are pulsed, including pulsed low intensity EMFs. While there is no doubt that these are very interesting observations on what are clearly non-thermal effects, they do not provide a biophysical model explaining how microwave hearing may occur. It is important, therefore to ask whether such microwave hearing could be caused by VGCC activation. It has been shown that hearing involves the activation of the VGCCs (Joiner and Lee, 2015). Furthermore, various otolaryngological conditions, including tinnitus, involve excessive VGCC activity, such that the calcium channel blocker, nimodipine is useful in their treatment (Monzani et al., 2015). These findings tells us that microwave hearing may be produced by VGCC activation. Consequently, microwave hearing may be interpreted as providing further support for the VGCC mechanism.

Following microwave hearing, Dr. Belyaev (2015) discusses plasma membrane and ion models. Here the VGCC mechanisms fit into the scheme, as do the other voltage-gated ion channels and the plant TPC channels, all discussed above as being activated by their voltage sensor following EMF exposures.

Finally, Dr. Belyaev (2015) discusses possible direct effects of EMFs on DNA, possibly leading to changes in chromatin structure and/or nuclear structure. There is a literature showing that aqueous solutions of DNA absorb microwave EMFs much more efficiently than do identical solutions not containing DNA. This clearly shows that DNA has a high absorbance of the EMFs, Furthermore, there are studies showing such dissolved DNA, when it absorbs such EMFs, undergoes structural changes as measured by biophysical techniques. All of this suggests that DNA is a plausible potential target for the EMFs. The problem is what are the predicted effects of such changes in DNA structure in living cells and organisms? Dr. Belyaev spends almost a page and a half in his paper discussing various possible models of interactions of DNA or of chromatin with EMFs. But again, how do we test any of these in living cells to demonstrate a role of such DNA or chromatin changes in producing any specific or general biological effects? Given the extraordinary complexity of living cells and organisms, there are only two powerful ways of demonstrating causal roles in such living cells and organisms. These are to use genetics or to use specific pharmacological agents. The extraordinary power of each of these approaches comes from the fact that these approaches allow researchers to vary one variable at a time out of the thousands of interacting variables in a living cell, allowing us to ask does that specific variable have a causal role in determining a specific response. But these two approaches can be used when specific proteins have specific roles, not when you are looking at the role of DNA structural changes, Fröhlich's theory, radical pair mechanisms or electrosoliton models. Fortunately the VGCC mechanism does allow this approach by studying various classes of calcium channel blockers, so here we do have hard data on widespread causal roles of VGCC activation in producing EMF effects.

8. Two other models for producing non-thermal effects

With the possible exception of the electrosoliton model, the author does not find any of the models discussed by Dr. Belyaev (2015) to have substantial evidence for roles in producing EMF effects. There are two other models which may be more compelling, each of which either produces increased [Ca2+]i.

Six studies have supported the view that calcium cyclotron resonance, has a role in producing biological effects produced by *certain specific frequencies* which can interact with Ca^{2+} ions to produce a cyclotron-like resonance (Foletti et al., 2010; Gaetani et al., 2009; De Carlo et al., 2012; Lisi et al., 2008; Pazur and Rassadina, 2009; Pazur et al., 2006). In each case, the effects involved a very specific frequency which produces the calcium cyclotron resonance and in three studies, these frequencies were shown to produce increases in [Ca2+]i levels. In the De Carlo et al. (2012) study, the calcium channel blocker nifedipine was shown to greatly lower the apparent calcium cyclotron resonance effect. This finding strongly suggests that the calcium cyclotron resonance can feed Ca^{2+} ions into the VGCCs, thus increasing the flow of Ca^{2+} ions through the VGCCs into the cell following EMF exposure. The frequencies studied here for cyclotron resonance, one was close to 7 Hz and the other was close to 50 Hz, are both in the extremely low frequency range and consequently are not relevant to microwave frequency effects. The finding that only very specific calcium cyclotron resonance frequencies produce these effects is the main evidence for this mechanism.

It is now well established that there is a magnetoreception mechanism found in many animals that can detect and respond to the very low intensity geomagnetic field. This has been most studied in bees and in birds, both of whom use it for navigation. This has been suggested to involve tiny particles of magnetite which occur in bacterial, animal and plant cells, including human cells. Kirschvink (1992) first proposed a model of how such a mechanism might act. He proposed that magnetite particles may be tethered through a microtubule and/or microfilament or perhaps other fibers to a mechanosensitive channel, such that tiny magnetic forces could open the mechanosensitive channels, allowing cation flow into the cells. It is still uncertain what mechanosensitive channel or channels might be involved, but most of the candidates are channels that allow both sodium and calcium to flow into cells. Hsu et al. (2007) suggested that such magnetite particles were linked in honeybees to an undefined calcium channel, such that magnetic field exposure produces increases in [Ca2+]i. The worm Caenorhabditis elegans had been shown to have a geomagnetic orientation system. Vidal-Gadea et al. (2015) found that certain specific neurons in C. elegans which may be geomagnetic sensory neurons, very low intensity geomagnetic fields could produce increases in [Ca2+]i in those specific neurons, even when they had no synaptic inputs, suggesting that these neurons themselves acted as geomagnetic sensors.

Cadiou and McNaughton (2010) reviewed the literature on a magnetite-based magnetoreception system in birds and its role in avian migration. They also reviewed findings on neurons found in the trigeminal nerve of birds, where magnetic fields as low as 200 nT can activate specific neurons. Trains of action potentials are produced by magnetic fields, plateauing in the region of 20–100 mT. Latency in a study presented by Cadiou and McNaughton (2010) was about 4 s, but other studies have reported latencies of about 2.5 s. Therefore these are rapid effects. Cadiou and McNaughton (2010) also discuss possible roles mechanosensitive channels, including a model similar to that proposed by Kirschvink (1992) and also three other models, each involving different ways of coupling forces on magnetite to opening of a channel. Magnetoreception has also been reported to occur in a mammal, the mole-rat (Wegner et al., 2006). There are also studies of magnetic compass orientation in salmonids, newts, sea turtles and other rodents. There is evidence in Drosophila, that a magnetic structure attached to cryptochrome is involved in magnetoreception, as opposed to magnetite.

The two mechanisms described in this section have minor roles, only acting, as far as we can tell, in very specific situations. The calcium cyclotron resonance mechanism only acts with a few specific frequencies in the extremely low frequency range. The magnetoreception mechanism only acts, as far as one can tell, on detecting the weak geomagnetic fields and only acts, as far as one can tell, in certain specific neurons. It is possible that this view may change with regard to the magnetoreception mechanism but what is clear is that the VGCC mechanism is vastly more important than either of these mechanisms, acting in diverse cell types and acting to provide responses to a very wide frequency range and even to static electrical fields and static magnetic fields. Because static magnetic fields only place forces on moving electric charges, this produced a puzzle on how they can activate the VGCCs. Pall (2013) suggested that the solution to that puzzle is that the plasma membrane of animal cells is often moving, such that the charges in the voltage sensor are also moving and can, therefore, have forces placed on them by the static magnetic fields. These static magnetic fields, activating the VGCCs can be relative low intensity but probably must be much higher intensity than the extraordinarily weak geomagnetic fields. The reader is referred to Lu et al. (2015) for empirical information from an important static magnetic field study, where those static magnetic fields activate both VGCCs and voltage-gated sodium channels.

9. Foster and Moulder on Wi-Fi

The Foster and Moulder (2013) paper argues that there are no and cannot be any health effects of Wi- Fi. The first 7½ pages of the paper are, however, largely irrelevant to that issue. These pages discuss such issues as predicted peak power output, incident power density and the FCC and international safety guidelines. They also discuss specific absorption rate (SAR) values, a measure of heating. Because it is now established, as discussed above that thermal effects are not the relevant mechanism of non-thermal effects and that VGCC activation is the main mechanism of such effects, this whole section is irrelevant. Foster and Moulder (2013) discuss the issue of biological effects, praising 7 studies listed in table 4 of their paper as having “well-characterized exposure systems” of well defined SARS values, reporting that there were no effects in the rats or mice in those 7 studies. Those 7 studies are Laudisi et al. (2012), Sambucci et al. (2010), Aït-Aïssa et al. (2010, 2012, 2013) and Poulletier de Gannes et al. (2012, 2013). The first two studies come from one research group and the other five from another, albeit with some shared personnel.

Six or those seven studies (Sambucci et al., 2010; Aït-Aïssa et al., 2010, 2012, 2013; Poulletier de Gannes et al., 2012, 2013) used an exposure system described by Wu et al. (2009) that is important here and that was claimed to produce a near uniform exposure. Laudisi et al. (2012) used a somewhat similar exposure system of Ardoino et al. (2005), albeit another one that is also claimed to produce near uniform exposures. The important features here of the Wu et al. (2009) exposure system need to be examined in the light of the fact that, as discussed above, artificial EMFs are polarized with the polarization producing much larger biological effects than natural non-polarized EMFs (Belyaev, 2005, 2015; Panagopoulos et al., 2015a). The probable important feature of these polarized EMFs is that they put much larger forces on electrically charged groups (Panagopoulos et al., 2015a); since such forces are central to VGCC activation via the voltage sensor, as discussed above, they are likely to be central to the production of most biological effects. Let's examine Wu et al. (2009) with that issue in mind. It uses a large chamber surrounded by 1 mm aluminum mesh wire mesh to provide reflections of the EMFs. The chamber in which animals are exposed on a platform at its center, is also surrounded by antennae in all 6 directions (up, down, all four horizontal directions) such that each antenna is broadcasting with one polarization is opposed (at 180°) by another broadcasting with the 180° opposite polarization, as well as by four other antennae, broadcasting with 90° different polarization in each of the four possible directions. This produces a field that is more like a non-polarized EMF rather than the usual polarized artificial EMF. This move toward non-polarization is further exacerbated by the aluminum wire reverberation system whose reflections will generate vast numbers of reflections of different polarity, like a non-polarized EMF. The consequences of this is that the structure of this exposure system is clearly very different from that seen in Wi-Fi or any other artificially produced EMF that we may be exposed to, with biological effects produced via electrical forces being vastly less. Consequently this exposure system is not only inherently different from genuine Wi-Fi, it is predicted to be inherently less active than genuine Wi-Fi, regardless of what EMFs are being fed into the 6 antennae.

There is a second type of consequence of using such reverberation exposure systems. Because of the many reverberations occurring, the path lengths of different photons reaching a specific point in the exposed tissue, will often be quite different from each other, such that the phase of the EMFs produced will also be quite different from each other. This leads to the possibility of destructive interference and thus a second mechanism which is predicted to lead to substantial decreases in the intensity of the exposures. Because exposures are usually predicted by groups using such exposure chambers without considering such destructive interference, rather than being measured, the actual exposures may be substantially lower than are the predicted exposures. Both the polarization effect and the possible difference between predicted exposure and actual exposure were considered in an earlier study.

Vian et al. (2006), using a different reverberation exposure chamber, discussed in Fig. 1 of that paper, how the various reverberations lead to the initial polarized EMF being converted to a non-polarized or at least, less polarized EMF. They also on p. 69 if that paper compared the predicted with the measured amplitude and found that the measured amplitude was only 78% of the predicted amplitude. These findings suggest that both of the lowered polarization and destructive interference discussed in the previous two paragraphs can have substantial roles in lowering biological responses produced when using such reverberation exposure chambers.

Laudisi et al. (2012) used a different exposure system, that of Ardoino et al. (2005) where the vast majority of the exposure is produced from reflections off a long cylindrical surface in a TEM cell, where the curvature of the cylinder will also produce a largely non-polarized EMF and different reverberation paths and consequent destructive interference, may both be expected to occur. Consequently the predicted low biological activity of EMFs produced by the Wu et al. (2009) system may be expected to also occur from this TEM exposure system Ardoino et al. (2005). It is not possible to study biological effects of EMFs from Wi-Fi, cell phones or any other important exposures using such exposure systems because of the polarization changes they produce from the original polarized EMFs and because of destructive interference.

Let's now shift to the issue of the important role of pulsations in producing biological effects and ask whether the EMFs fed into the antennae have pulsation patterns similar or different from genuine Wi-Fi. Poulletier de Gannes et al. (2012) used a non-pulsed (continuous wave) as did Wu et al. (2009), an EMF which will have, therefore, much lower biological effects that genuine Wi-Fi with its myriad of pulsations (Maret, 2015). The other 6 studies (Laudisi et al., 2012; Sambucci et al., 2010; Aït-Aïssa et al., 2010, 2012, 2013; Poulletier de Gannes et al., 2013) used computers with Wi-Fi cards. Such Wi-Fi cards are designed to communicate with genuine Wi-Fi antennae, but are used here to communicate with each other, using two such computers to generate “Wi-Fi”. How the EMFs so generated compare with the pulsations of genuine Wi-Fi is a complete mystery and none of these papers provide any information to allow the reader to make such a comparison. It follows that these studies (Laudisi et al., 2012; Sambucci et al., 2010; Aït-Aïssa et al., 2010, 2012, 2013; Poulletier de Gannes et al., 2013) are not studying genuine Wi-Fi, even before the effects of the reverberation chamber and the reader is left with no evidence to compare these original EMFs with genuine Wi-Fi. In summary, then none of the EMFs used in these studies are genuine Wi-Fi, with them differing from genuine Wi-Fi in three different ways: the antenna locations produce a substantial difference from genuine Wi-Fi regarding EMF polarization and this is further exacerbated by the effects of the aluminum mesh reverberation producing further lowering of any polarization; differences in path lengths of different photons produce substantial destructive interference; the initial EMF fed into the antennae differs substantially from genuine Wi-Fi, with the main concern here being due to the issue of pulsation patterns and biological effects.

Let's shift now to the claim made by Foster and Moulder (2013) that there were no effects found in any of these 7 studies. Rothman et al., Modern Epidemiology, 3rd Edition is a highly respected source of information, cited over 18,500 times according to the Google Scholar database. It states (p. 151, bottom) that: "A common misinterpretation of significance tests is that there no difference between two observed groups because the null test is not statistically significant, in that P is greater that the cutoff for declaring statistical significance (again, usually .05). This interpretation confuses a descriptive issue (whether two observed groups differ) with an inference about the superpopulation. The significance test refers only to the superpopulation, not the observed groups. To say that the difference is not statistically significant means only that one cannot reject the null hypothesis that the superpopulation groups are the same; it does not imply that the two groups are the same." It follows that the claim of "no effect" that Foster and Moulder (2013) make about each of these 7 studies in Table 4 of their paper is false because one can never legitimately make such a claim; one can at most claim that there were no statistically significant differences.

However there are other reasons to reject those claims that need to be considered for each of these 7 studies. Each of these 7 studies fails to provide raw numerical data, the lack of which is problematic, given the other flaws that follow. **1).** Laudisi et al. (2012) finds in Table 2, that two T cell populations are statistically significantly different in prenatally exposed mice vs sham controls: DP and CD4SP cells are significantly affected by exposure in mice at 26 weeks after birth; CD4SP cells are affected in female mice at 5 weeks after birth ($P < .02$ in each case). Furthermore in each of the measurements in Laudisi et al. (2012), only 11 or 12 mice were studied, tiny numbers. It follows that claims in Foster and Moulder (2013) that there were no effects are false or misleading for 3 distinct reasons: You can never make such claims even in large studies; there were 3 comparisons each of which showed statistically significant effects; this study was done with tiny numbers of animals being compared and thus had extremely low statistical power. **2).** Sambucci et al. (2010) also had a tiny numbers, with 11 or 12 per group studied in Table 2, from 6 to 35 studied in Table 3 and 6 to 12 studied in Table 4. The claims of no statistically significant effects in Figs. 2, 3, 4 and 5 are based on the tiny numbers in Table 3, are therefore, based on studies with very low statistical power. **3).** The first part of the Aït-Aïssa et al. (2010) paper focused on GFAP values, a measure of gliosis, which is a risk factor for glioma formation. The groups studied in Fig. 4 of Aït-Aïssa et al. (2010) range from 3 to 10, so again we have tiny numbers and the authors report that none of the exposures, SAR = .08, = .4. or = 4 W/Kg produced statistically significant changes according to their statistical calculations. As in the other studies, no raw data are provided but Fig. 4 provides bar graph information which includes median values for each of the 10 different regions of the brain in these rats, control rats and also rats exposed either pre-natally or both pre-natally and post-natally. For 5 of those brain regions, M4, CA1, CA2, CA3 and DG, the median values are high enough that one can see which are higher and which are lower from the graph. It appears to this author that the median values go up from the sham exposures to the lowest intensity (= .08), that they drop going to the next intensity (= .4) and that they go up going to the highest intensity studies (= 4). You may recall (see above) that there are certain windows of exposure that give the highest biological response but with both lower and higher intensities giving lower responses. It follows that the complex apparent dose-response curve of Aït-Aïssa et al. (2010), can be explained by these window effects. The question is whether any such apparent changes are statistically significant? I did, therefore a Chi-square analysis of these data, to determine statistical significance, using both the only prenatal and both prenatal and postnatal exposures (see Fig. 4 in Aït-Aïssa et al., 2010). Those data show that in 10 out of 10 cases, the median value increased going from sham to .08 ($P < .002$.). Similarly, in 10 out of 10 cases, the median value drops going from .08 to .4 ($P < .002$). However in 8 out of 10 cases, the median value increases going from .4 to 4 ($P < .07$), falling just short of statistical significance. The median values increased with exposure, comparing the sham values with the values at 4 ($P < .02$). It follows from this, that three of the comparisons show statistically significant changes, and the fourth falls just short of statistical significance. Does this mean that that we should conclude that Wi-Fi can cause gliosis and thus possibly gliomas? No, but only because they did not study Wi-Fi. It should be noted, however that the long-term effects on the brain from pre-natal exposures may be relevant to autism causation.

4). Poulletier de Gannes et al. (2012) also suffered from tiny numbers in their study, with 12 to 15 rats studied in each group in Fig. 1, only 5 females in each group in Table 1, 12 to 15 rats in each group in both Table 2 and Table 3. **5).** Aït-Aïssa et al. (2012) also suffers from tiny numbers of rats in the various studies. It used from 9 to 12 pregnant female rats in each group to attempt to assess EMFs impact of reproduction; it used 9 to 12 juvenile rats to determine if EMFs act to change antibody production; it used 9 to 12 young rats to determine whether EMFs impact growth over time. These tiny numbers mean that failure to find statistical significant changes has very low power to support any inferences. **6).** Aït-Aïssa et al. (2013) had similar problems with tiny numbers, 6 to 12 in Fig. 5, 5 to 11 in Fig. 8 and 6 to 12 in Fig. 9. **7).** Poulletier de Gannes et al. (2013) also suffers from tiny numbers. Fig. 1 groups each had 12 males or females and there were also groups of 12 studied in Table 1, Fig. 2 and Table 2. Regarding, the authors give no information regarding statistical significance or lack thereof; rather they only state that the values of these groups were "similar", without providing a definition of "similar". However in comparing the values of testis weight and epididymis weight at 4 W/Kg exposure vs sham control, they provided values for the mean and standard error of the mean (SEM). It is usually the case that when the mean values differ by more than 2.4 times the SEM, the difference is statistically significant. Here the testis weight, comparing sham with 4 W/Kg, values differed by 3.18 times the SEM and the epididymis weight differed by 3.40 times the SEM, each arguing strongly for statistical significance. This raises the question of why the authors failed to provide their P values?

An additional flaw of these 7 supposed Wi-Fi studies is that they each studied exposures of 2 h per day, 5 days per week except for one that only studied one hour per week, 5 days per day. Given that many people are exposed to Wi-Fi fields for 5, 6, 8 or more hours per day, this is another factor which argues that these studies may have been set up to minimize any effects seen.

To sum up the other flaws:

1. The 6 antennae of the reverberation chamber used in 6 out of 7 studies, minimized probable effects produced through the arrangement of the antennae in such a way as to greatly lower the polarization of the EMFs.
2. The use of 1 mm aluminum wires to produce the reverberation reflections, further decreases such polarization, again lowering probable effects. These structures are clearly very different from those found in genuine Wi-Fi, emphasizing the point that these are not genuine Wi-Fi studies, because of 1 and 2 here.
3. Differences in path lengths for different photons, produced by reverberation produce substantial destructive interference.
4. Furthermore the EMFs fed into the antennae are not genuine Wi-Fi either. It follows from this that claims that these are studies of genuine Wi-Fi made by both the authors of these individual studies and by Foster and Moulder (2013) are false.
5. The claims made by Foster and Moulder (2013) that there are no effects produced are also false; the most that may be legitimately concluded is that there is no statistically significant evidence of effects.
6. Each of the 7 studies used only tiny numbers of animals in each group studied, such that lack of statistical significance, because of the low power of these studies, drastically limits the drawing of inferences.
7. Finally, 3 out of 7 had evidence of statistically significant effects,

with each of these being ignored by Foster and Moulder.

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