Biological Effects of Electromagnetic Fields AMMG Meeting Denver CO October 30, 2022

Martin L. Pall
Professor Emeritus of Biochemistry
and Basic Medical Sciences
Washington State University
martin_pall@wsu.edu

Disclosure

No Relevant Relationships with a Commercial Interest to Disclose

How are the non-thermal effects produced?

30 studies have shown that non-thermal effects of microwave/other frequency electromagnetic fields (EMFs) can be blocked or greatly lowered by calcium channel blockers. (6 different types of VGCC calcium channel blockers were used in these studies, each having distinct chemical structures often binding to different sites to block channels.)

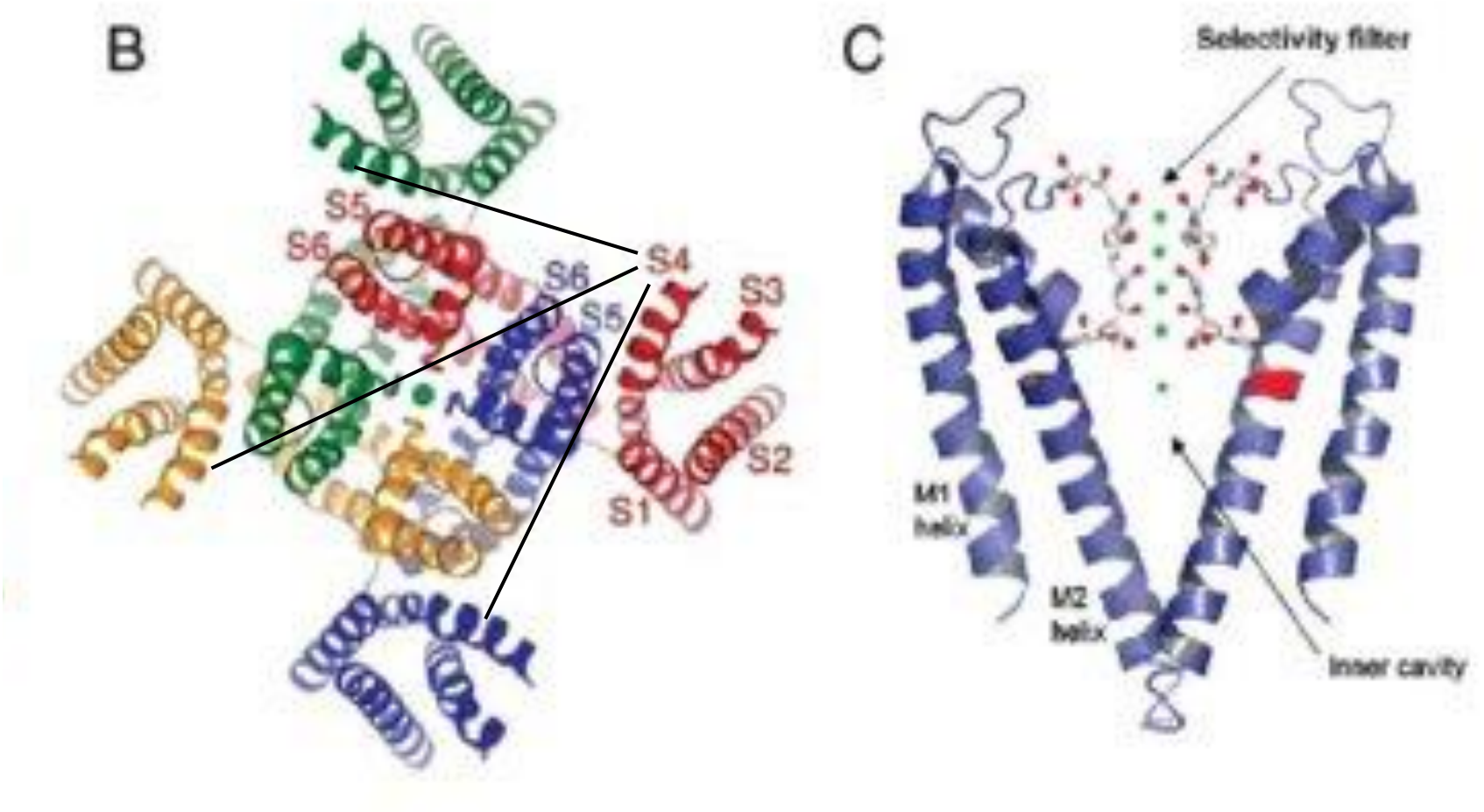
Mechanism established in my 2013 EMF paper – widely recognized by having been cited 426 times in the scientific literature (Google Scholar)

Electronically generated EMFs are coherent, emitted with a particular vector direction, with a specific frequency, phase and polarity; for these reasons, coherent EMFs place vastly stronger electric and time-varying magnetic forces on electrically charged groups than do natural incoherent EMFs. Pall ML. Millimeter (MM) wave and microwave frequency radiation produce deeply penetrating effects: the biology and the physics. Rev Environ Health 2021; Pre-published online by De Gruyter May 26, 2021 https://doi.org/10.1515/reveh-2020-0165
MM-wave electric field is rapidly absorbed by body tissues but magnetic fields are highly penetrating. ***The time-varying magnetic fields of coherent MM-waves can produce large highly penetrating effects.***

Channels	Citation
L-type, T-type, N-type, P/Q-type voltage-gated calcium channels (VGGCs)	Pall, 2013
Voltage-gated sodium, potassium and chloride (anion) channels	Pall, 2018
Calcium-activated potassium channels (BKCa)	Pall, 2021
TPC, GLR3.3, GLR 3.6 (in plants)	This paper

Channels activated by EMFs—Each is controlled by a similar voltage sensor

Ravens and Wettver, Cardiovasc Res 2011:89:776-785 (potassium channel)



Throughout the technologically “advanced world” all “safety guidelines” are based on average intensities (6 min or 30 min). Allowable levels based only on thermal effects.

Table: 1998 ICNIRP “Safety Guidelines”

	Frequency range	**Whole-body SAR (averaged over 6 minutes**	**Localized SAR (head & trunk, averaged over 6 minutes**	**Localized SAR (limbs, averaged over 6 minutes**
Occupational exposure	100 KHz-10 GHz	0.4 (W/kg)	10 (W/kg)	20 (W/kg)
General public exposure	100 KHz-10 GHz	0.08 (W/kg)	2 (W/kg)	4 (W/kg)

Other fatal flaws:

1. 12 reviews each show that pulse modulated EMFs produce, in most cases, much stronger effects than non-pulsed EMFs of the same average intensities.
2. Nanosecond pulses (1 ns to 1 μs) produce effects – also via VGCC activation.
3. Intensity windows
4. Frequency windows—specific frequencies producing effects at intensities orders of magnitude lower than needed for nearby frequencies to produce effects. Thought to be due to resonance with biological target.
5. Different cell types respond very differently to EMFs – using identical methods.
6. Smarter devices – more pulse modulation.
7. The failure of the telecom industry, ICNIRP and the other regulatory agencies to pay attention to the role of EMF coherence is especially puzzling. ICNIRP published a paper (1997) on near visible frequency effects which acknowledged the importance coherence in determining EMF effects but subsequently completely ignored the role of coherence. The telecom industry knows full well the importance of coherence in telecommunication. Emitting antennae emit coherent EMFs which transfer information receiving antennae through electric forces – forces requiring coherence.

Current US/international safety guidelines only based on thermal (heating) effects, even though many non-thermal effects occur at levels many orders of magnitude lower.

Examples of non-thermal biological effects:

1. Lowered fertility (27 different reviews).

Changes in structure of testis, ovaries; lowered sperm count, motility, quality; lowered number of follicles (eggs), increased spontaneous abortion, lowered levels of 3 sex hormones, lowered libido

2. Neurological/Neuropsychiatric effects (36 reviews)

Widespread changes in neurotransmitter activities. Insomnia, fatigue, depression, headache, lack of concentration/cognitive dysfunction, anxiety/stress agitation, memory dysfunction, etc. Major brain structural changes seen in animals. Effects on the electrical activity of the brain (EEGs) - 38 experimental studies.

3. Cellular DNA damage, 3 types (26 reviews)

Single & double DNA breaks, oxidized bases (8-HOdG); cause both cancer and germ-line mutations

4. Apoptosis, programmed cell death (16 reviews)

Lead to both reproductive and neurodegenerative effects

Examples of non-thermal biological effects

5. Oxidative stress, free radical damage (28 reviews)

6. Endocrine (hormonal effects) (16 different reviews).

Both non-steroid and steroid hormones systems affected; in some cases EMFs can produce both increased and decreased hormone activity under different conditions.

7. Excessive intracellular calcium [Ca2+]i (16 reviews)

Underlying cause of almost everything else.

8. Cancer (44 reviews)

Increases initiation of carcinogenesis, tumor promotion and progression, including increased tissue invasion and metastasis

9. Cardiac effects via electrical control of heart (14 reviews).

Tachycardia; chronic exposures can lead to bradycardia; both cause arrhythmia; also get heart palpitations; sudden cardiac death.

Sleep disturbance/insomnia, headache, depression/depressive symptoms, fatigue/tiredness, dysesthesia, concentration/attention dysfunction, memory changes, dizziness, irritability, loss of appetite/body weight, restlessness/anxiety, nausea, skin burning/tingling/dermographism, tinnitus & EEG changes.

Martin L. Pall, Microwave frequency electromagnetic fields (EMFs) produce widespread neuropsychiatric effects including depression, J Chem Neuroanatomy 75 (2016) 43–51.

11 additional reviews found similar EMF effects, including 5 published reviews on people living near cell phone towers (mobile phone base stations).

There are 24 additional reviews showing other neurological effects of EMFs.

Cardiac effects include tachycardia, arrhythmia, bradycardia, heart palpitations, sudden cardiac death. Each of these are thought to be produced via EMF impacts on the VGCCs in the pacemaker cells in the sino-atrial node of the heart. Longer term effects may be produced via heart-failure like responses in the sino-atrial node.

These of these effects are each produced via EMF impacts on those pacemaker cells because of their high densities of VGCCs.

18 distinct types of evidence collectively show that EMFs cause Alzheimer's including extremely early onset Alzheimer's. **Pall ML. 2022.** Low Intensity Electromagnetic Fields Act via Voltage-Gated Calcium Channel (VGCC) Activation to Cause Very Early Onset Alzheimer's Disease: 18 Distinct Types of Evidence**. Cur Alzheim Res,** DOI: https://doi.org/10.2174/1567205019666220202114510

Involves both excessive calcium signaling and the peroxynitrite/oxidative stress/ inflammation pathway

EHS

prevention & treatment of EHS effects

Let's simply focus on the 5 most important findings:

1. **We have had in recent years a decrease in the age of onset of Alzheimer's; EMF occupational exposures are linked to increased incidence of Alzheimer's. Young people develop digital dementia from long exposure to cell phone or Wi-Fi radiation.**
2. **EMF pulses to rats given within one day or even within one second of one day cause very early Alzheimer's in rats – this is approximately the equivalent of 42 year old humans developing near-universal Alzheimer's.**
3. **If instead of giving the pulses in one day you give them once a day starting at the same time, the Alzheimer's is apparent much earlier (10 month old rats) – this is roughly the equivalent of 21 year old humans developing universal or near universal Alzheimer's. This may not be as ridiculous as it seems – young people exposed to hours per day of cell phone or high powered Wi-Fi radiation develop digital dementia!! (Jiang et al 2013 & 2016)**
4. **EMFs (in animals) and excessive [Ca2+]i in humans & animals each cause all important causes of Alzheimer's: excessive amyloid beta; synaptic dysfunction & synaptic structural changes; hyperphosphorylated tau; apoptotic and autophagic cell death**
5. **Most important study (El-Swefy et al, 2008) showed that rat exposed to low intensity 3G cell phone tower radiation (2 h/day) produced massive neurodegeneration in 4 weeks--34% of brain cells died. 11 measured and 4 observed changes were greatly lowered by VGCC blocker amlodipine.**

Lowered fertility (27 different reviews).

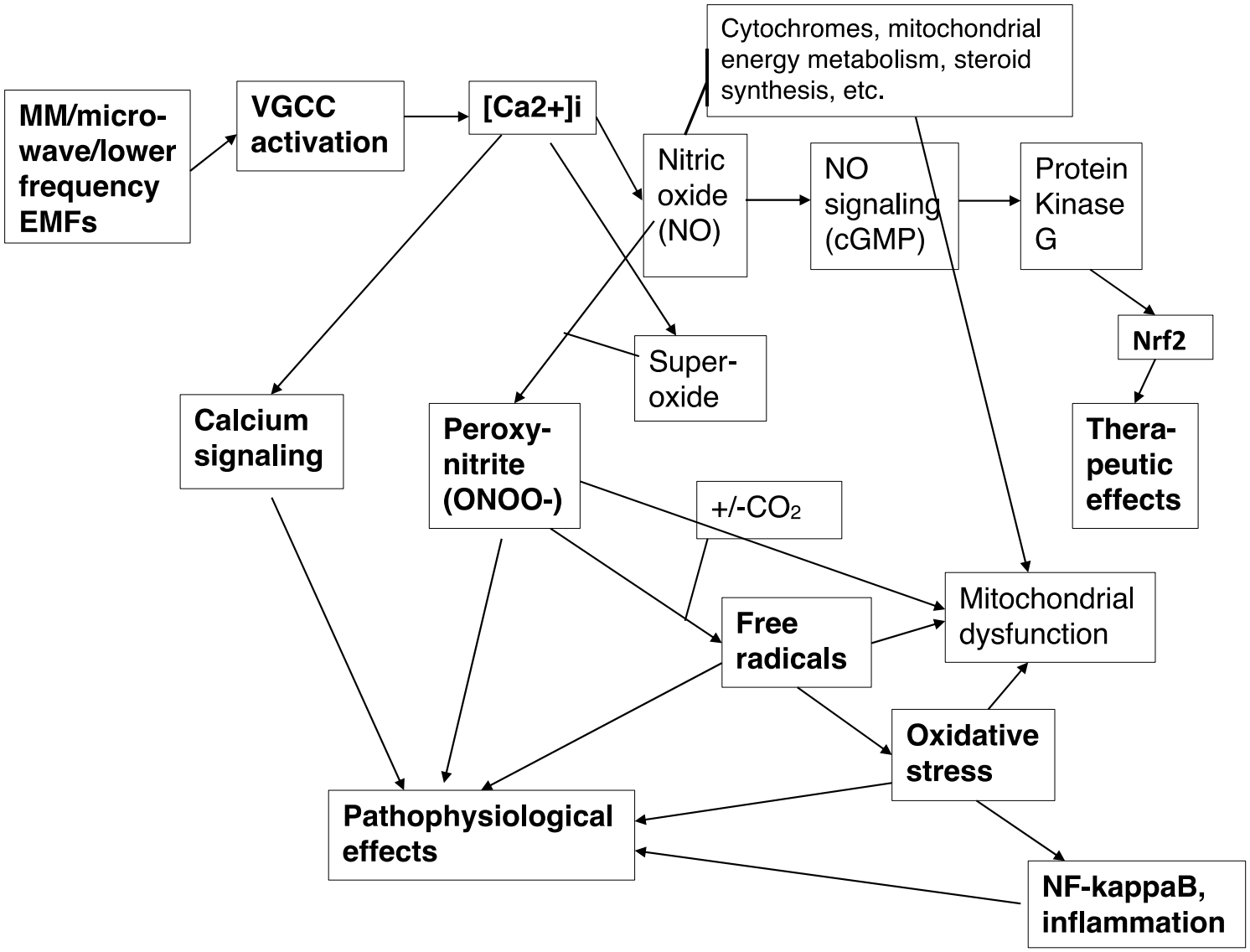
Changes in structure of testis, ovaries; lowered sperm count, motility, quality; lowered number of follicles (eggs), increased spontaneous abortion, lowered levels of 3 sex hormones, lowered libido

Sperm counts decreases are produced mainly by testis damagein rodents but other changes can be produced by direct EMF impacts on sperm – can use split semen sample.

***Experimental* studies on human semen show that EMFs produce:**

1. **Decreased motility.**
2. **Increased apoptotic cell death.**
3. **Large increases in structurally abnormal sperm.**
4. **Increases in DNA breaks (harder to study)**

Magras & Xenos (mice, 1997, cited 213 times)



How EMF effects are produced

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Electromagnetic hypersensitivity (EHS)

Blinded studies 4 of which show objectively measured hypersensitivity responses in apparent EHS patients:

1. Rea et al 1991. J Bioelectr 10:241-256.

2. Havas 2006. Electromagn Biol Med 25:259–68

3. Havas et al, 2010. In: Giuliani L, Soffritti M, editors. "Non-thermal Effects and Mechanisms of Interaction Between Electromagnetic Fields and Living Matter", European J Oncology — Library. National Institute for the Study and Control of Cancer and Environmental Disease Bologna: Mattioli; 2010. p. 273–300. 2010.

4. McCarty DE, et al. 2011. Int J Neuroscience 121:670-676.

5. Heuser & Heuser. 2017. Rev Environ Health. 32:291-299.

Greco F. 2020. Technical Assessment of Ultrasonic Cerebral Tomosphygmography and New Scientific Evaluation of Its Clinical Interest for the Diagnosis of Electrohypersensitivity and Multiple Chemical Sensitivity Diagnostics 2020, 10(6), 427

Belpomme D. et al, 2021. The Critical Importance of Molecular Biomarkers and Imaging in the Study of Electrohypersensitivity. A Scientific Consensus International Report. Int. J. Mol. Sci. 2021, 22(14), 7321

In my 2012 coherent EMF paper, (Pall ML. Millimeter (MM) wave and microwave frequency radiation produce deeply penetrating effects: the biology and the physics. Rev Environ Health 2021; Pre-published online by De Gruyter May 26, 2021) had a section in it where it was shown that: EMF exposure produced EHS-like changes in animal tissues; and that there was evidence from both animal and human study that EHS acted via hypersensitivity of the VGCCs! The question raised here is whether excessive $[Ca^{2+}]i$ can produce VGCC hypersensitivity via known mechanisms?

EMFs can act via calcium stimulation of three protein kinases, calcium/calmodulin kinase II (CAMKII), protein kinase A (PKA) and protein kinase C (PKC), to make the VGCCs hypersensitive to stimulation:

A Mechanism for the Direct Regulation of T-Type Calcium Channels by Ca2+/Calmodulin-Dependent Kinase II. Philip J. Welsby, Hongge Wang, Joshua T. Wolfe, Roger J. Colbran, Michael L. Johnson and Paula Q. Barrett. Journal of Neuroscience 5 November 2003, 23 (31) 10116-10121 (CAMKII)

Site-specific phosphorylation of the purified receptor for calcium-channel blockers by cAMP- and cGMP-dependent protein kinases, protein kinase C, calmodulin-dependent protein kinase II and casein kinase II. Holger JAHN, Wolfgang NASTAINCZYK, Axel RöHRKASTEN, Toni SCHNEIDER, Franz HOFMANN. Eur J Biochem 178:535-542. (PKA)

Calcium-dependent enhancement of calcium current in smooth muscle by calmodulin-dependent protein kinase II. John G. McCarron, J. Graham McGeown, Sheila Reardon, Mrtsuo Ikebe, Fredric S. Fay & John V. Walsh Jr Nature volume 357, pages 74–77 (1992)

Regulation of cardiac L-type calcium channels by protein kinase A and protein kinase C. TJ Kamp, JW Hell - Circulation research, 2000

Differential regulated interactions of calcium/calmodulin-dependent protein kinase II with isoforms of voltage-gated calcium channel β subunits CE Grueter, SA Abiria, Y Wu, ME Anderson… - Biochemistry, 2008

Voltage-dependent potentiation of the activity of cardiac L-type calcium channel alpha 1 subunits due to phosphorylation by cAMP-dependent protein kinase. A Sculptoreanu, E Rotman… - PNAS 1993 (PKA)

Crosstalk between G proteins and protein kinase C mediated by the calcium channel α1 subunit. GW Zamponi, E Bourinet, D Nelson, J Nargeot… - Nature, 1997 (PKC)

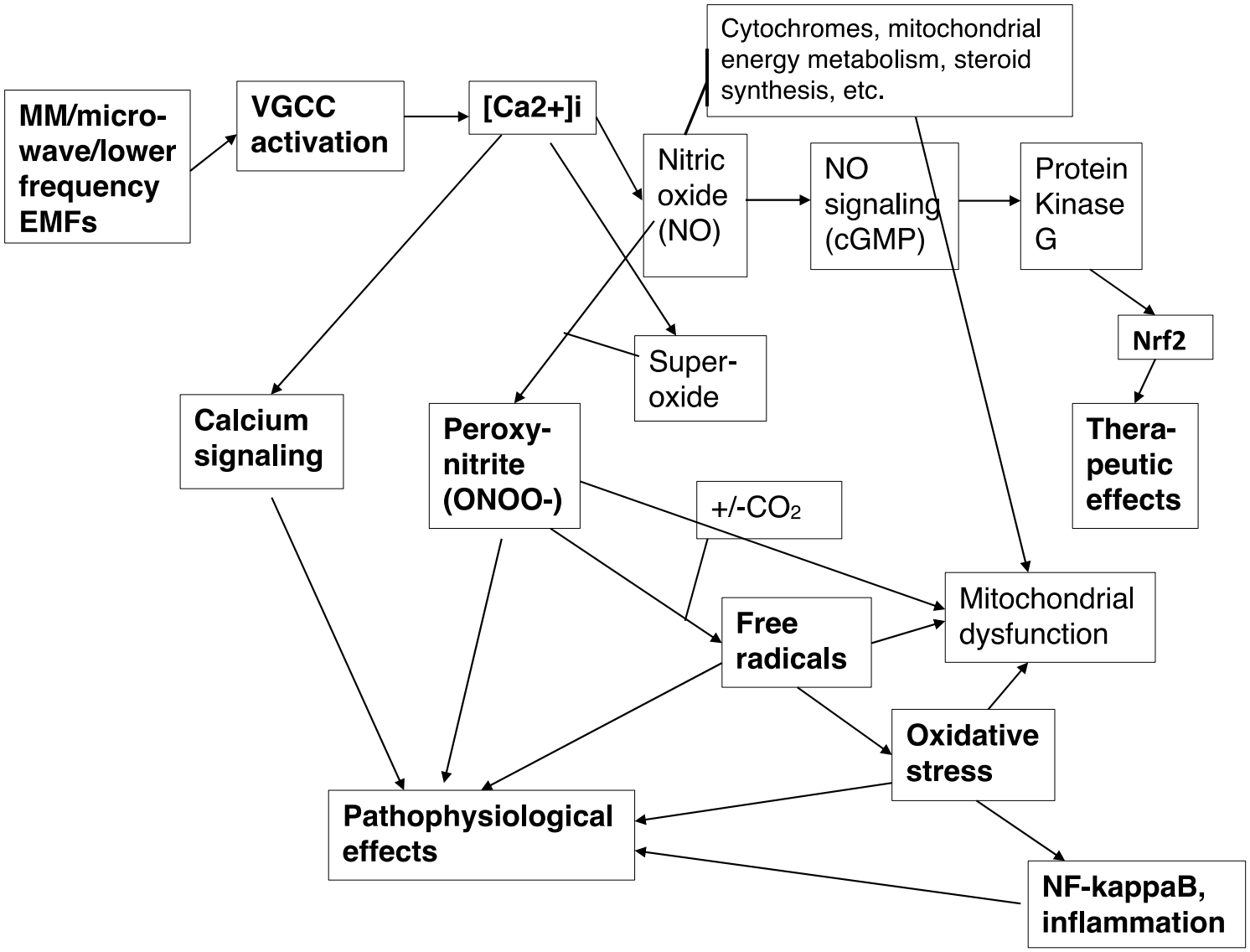
Overall outline of EHS mechanism:

EMFs → VGCC. → $[Ca^{2+}]i$ → CAMKII, PKA, PKC ↑ → VGCC sensitization activation

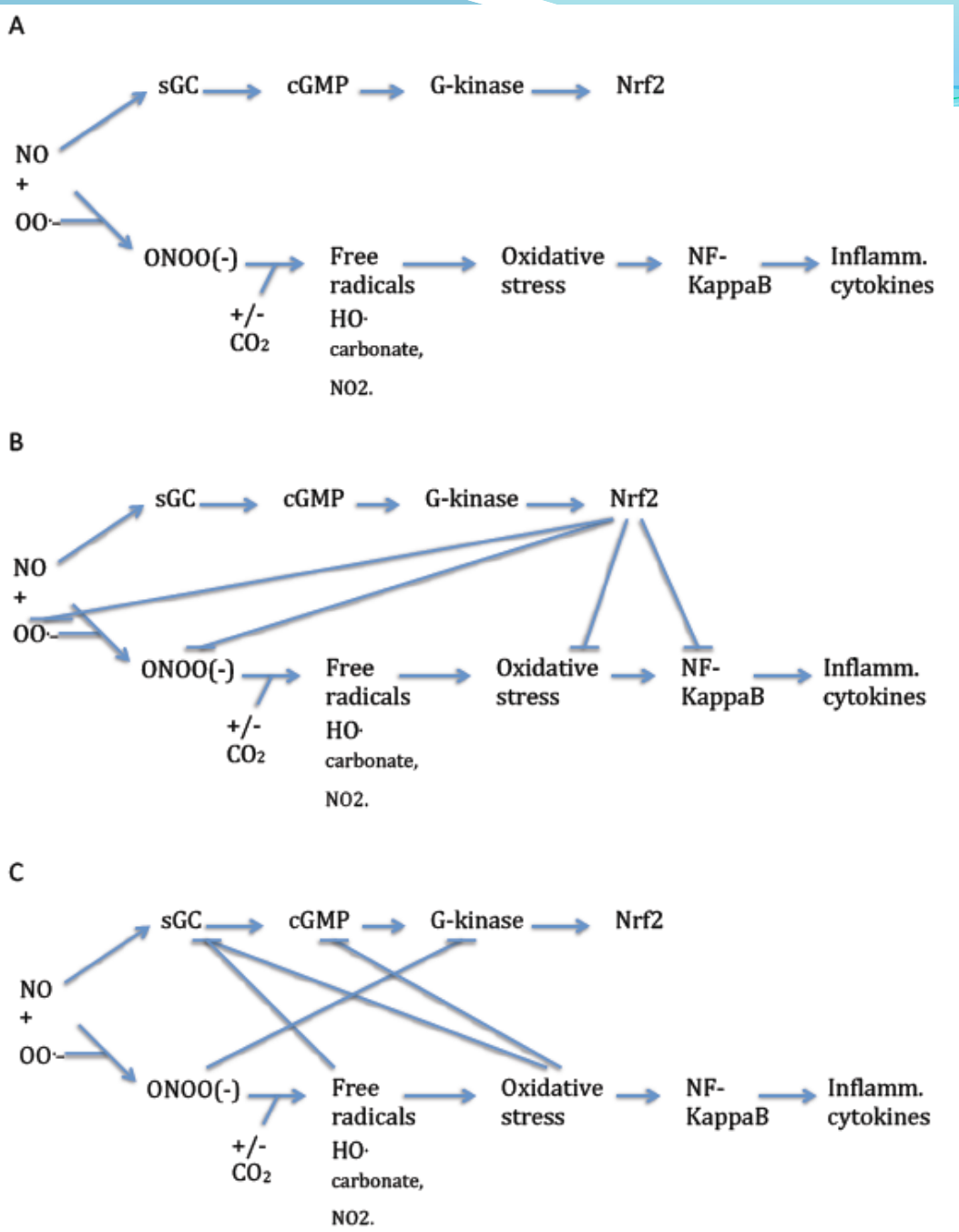
Prevention & Treatment:

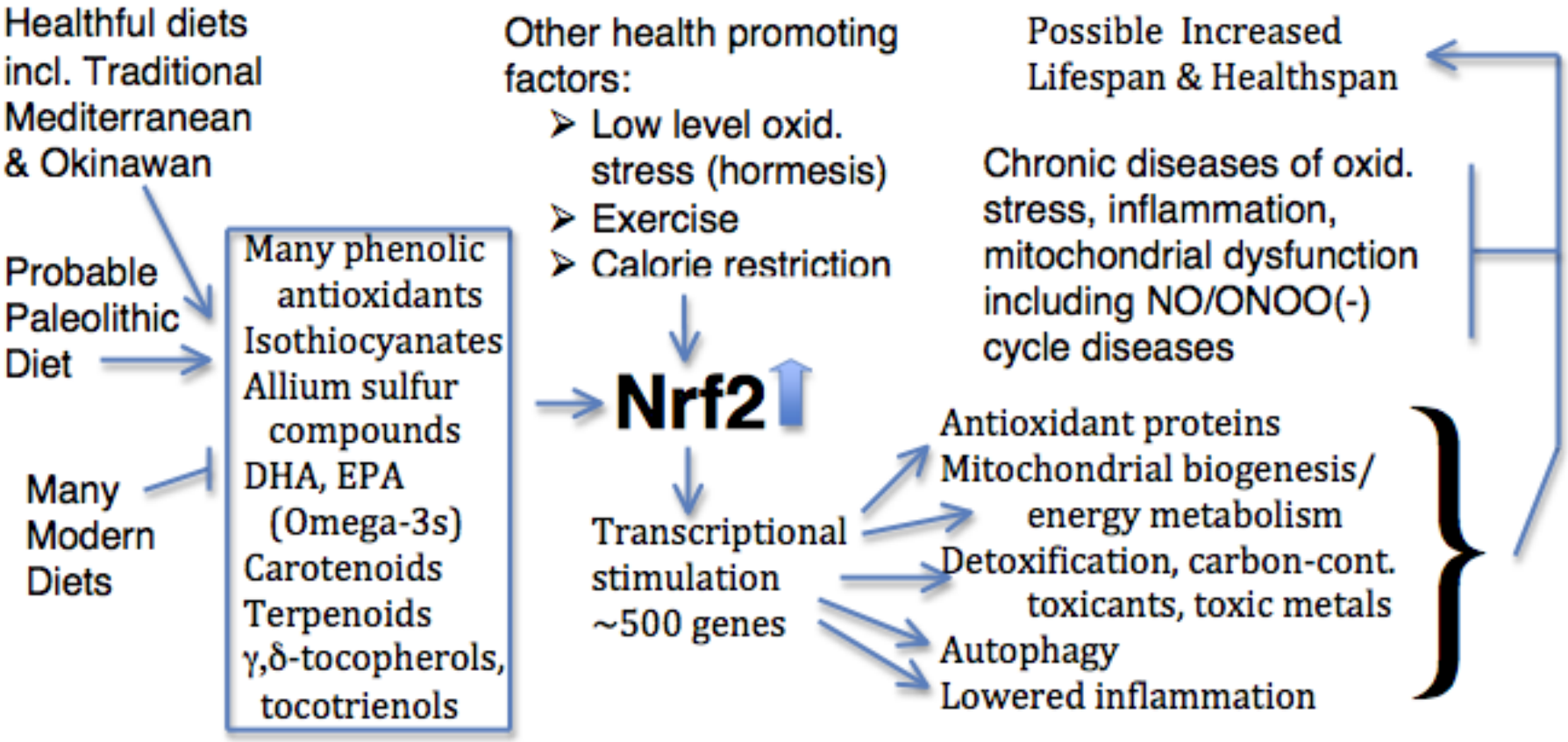
Of course the best approach is to prevent exposures but the telecom industry has used their "safety guidelines" to make it almost impossible to avoid all important exposures. As a personal comment, I will say that I do not use Wi-Fi (use cable connection to internet), I do not have a cell phone or cordless phone, I use a wired keyboard, wired mouse, wired printer. Wired connections are always preferred to wireless.

One can use shielding materials. Graphite paint and paints using large amounts of tiny metal particles act mainly by disrupting the coherence of the EMFs. Similarly, cloth containing large amounts of tiny metal fibers (often silver-containing) also disrupt coherence. These also absorb EMFs if they are grounded. Such cloth can be used as curtain materials and draped over a bed. A wide variety of shielded clothing is available including hoodies, hats, balaclavas, T-shirts, belly shields for pregnant women (may be useful for autism avoidance). All shielded cloth materials should be washed in special washing powder to avoid degrading the tiny metallic fibers.



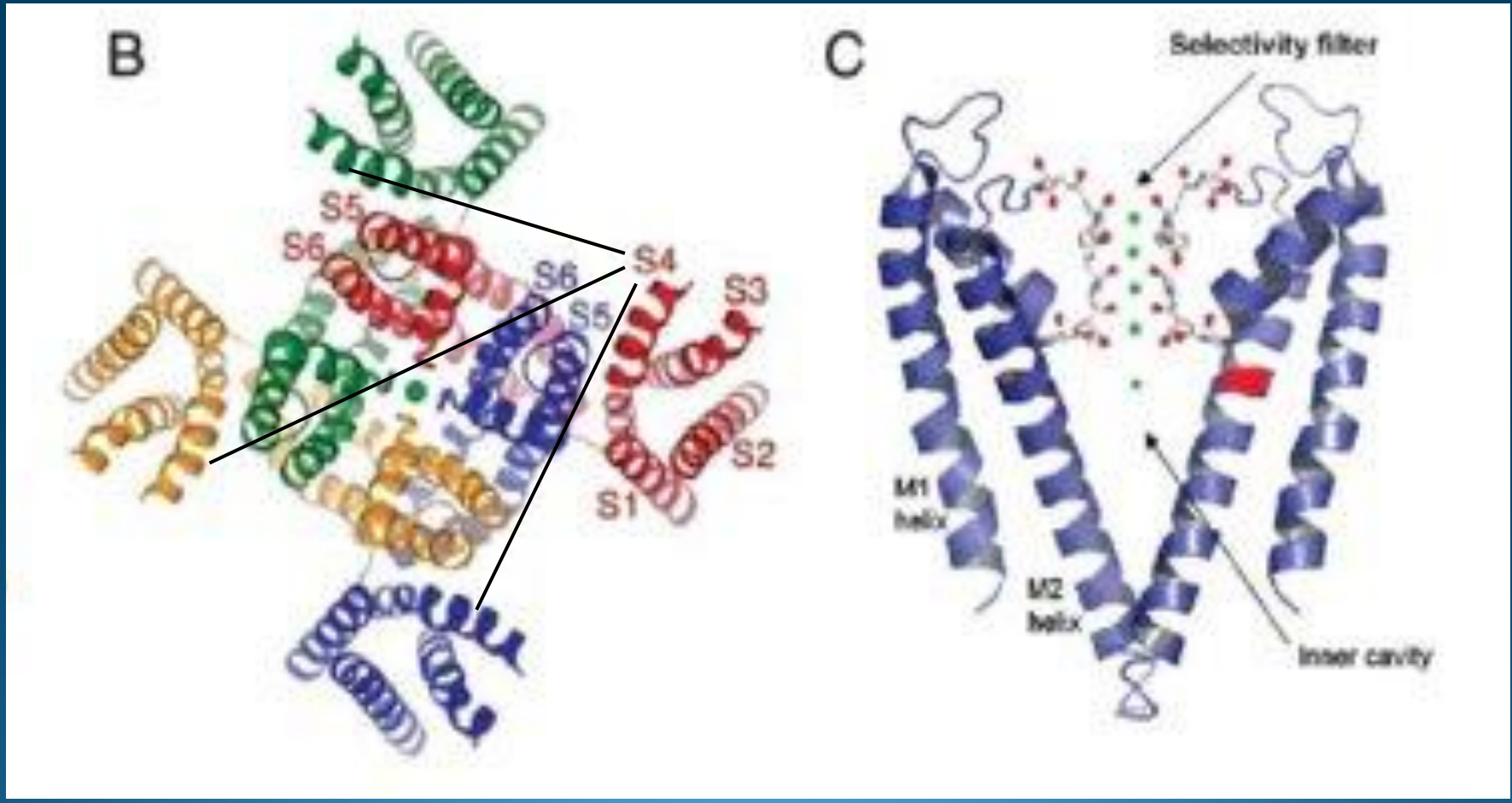
How EMF effects are produced


A
sGC
cGMP
G-kinase
Nrf2
NO
+
OO·-
ONOO(-)
+/-
CO2
Free
radicals
HO·
carbonate,
NO2.
Oxidative
stress
NF-
KappaB
Inflamm.
cytokines
B
sGC
cGMP
G-kinase
Nrf2
NO
+
OO·-
ONOO(-)
+/-
CO2
Free
radicals
HO·
carbonate,
NO2.
Oxidative
stress
NF-
KappaB
Inflamm.
cytokines
C
sGC
cGMP
G-kinase
Nrf2
NO
+
OO·-
ONOO(-)
+/-
CO2
Free
radicals
HO·
carbonate,
NO2.
Oxidative
stress
NF-
KappaB
Inflamm.
cytokines


Healthful diets incl. Traditional Mediterranean & Okinawan
Probable Paleolithic Diet
Many Modern Diets
Many phenolic antioxidants
Isothiocyanates
Allium sulfur compounds
DHA, EPA (Omega-3s)
Carotenoids
Terpenoids
γ,δ-tocopherols, tocotrienols
Other health promoting factors:
Low level oxid. stress (hormesis)
Exercise
Calorie restriction
Nrf2
Transcriptional stimulation ~500 genes
Antioxidant proteins
Mitochondrial biogenesis/ energy metabolism
Detoxification, carbon-cont. toxicants, toxic metals
Autophagy
Lowered inflammation
Chronic diseases of oxid. stress, inflammation, mitochondrial dysfunction including NO/ONOO(-) cycle diseases
Possible Increased Lifespan & Healthspan

The last thing I wish to discuss here is that EMFs, not only activate activate the VGCCs, but also can lower The activation produced by other EMFs. I will briefly suggest a mechanism and follow with an outline and How this may be used in practical ways.

Ravens and Wettver, Cardiovasc Res 2011:89:776-785 (potassium channel)



Three types of evidence:

1. Paired nanosecond pulses – second pulse with same or opposite polarity.
2. Intensity windows.
3. Studies where one EMF is studied with and without a second EMF given over the same time period.

There are two types of commercially available devices.

1. Device puts out an EMF.
2. Device contains crystals or other structured materials such that the reflections of an incoming EMF may off of the structured material may interfere with the ratcheting process.

Chemical Action in MCS

