Electromagnetic field exposures act via activation of voltage-gated calcium channels.

How this leads to diverse impacts on health

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In 1971, the U.S. Office of Naval Medical Research issued a report listing various types of health effects produced by exposures to microwave frequency electromagnetic fields (EMFs). In it they listed over 100 different effects produced by low intensity, non-thermal exposures.
These included:

40 different neuropsychiatric effects, including changes in brain structure and function, changes in various types of psychological responses and changes in behavior.
8 different endocrine (hormonal) effects.
Cardiac effects influencing the electrical control of the heart, including changes in ECGs and producing arrhythmias, changes that can be life threatening.
Chromosome breaks and other changes in chromosome structure.
Histological changes in the testes.
Cell death (what is now called apoptosis, a process important in neurodegenerative diseases).

The Naval report also provide approximately 2000 citations documenting these various non-thermal health effects of low intensity microwave EMFs.

Following 1971, there have been dozens of reviews including two others that were linked to the U.S. government that have reported various types of non-thermal health effects. There have also been thousands of additional primary literature citations reporting non-thermal effects. Among the effects that have been repeatedly documented are:

- Lowered male fertility including lowered sperm quality and function and also lowered female fertility (less studied). There are also reports of high levels of spontaneous abortion.
- Oxidative stress.
- Cellular DNA damage including single strand breaks and double strand breaks in cellular DNA and also 8-OHdG in cellular DNA.
- Cancer which is likely to involve these DNA changes but also increased rates of tumor promotion-like events.
- Widespread neuropsychiatric effects including depression.
- Therapeutic effects including stimulation of bone growth.
- Cataract formation (previously thought to be thermal, now known not to be).
- Breakdown of the blood-brain barrier.
- Melatonin depletion and sleep disruption.

Despite all of the evidence for non-thermal effects, our current safety guidelines/standards are all based on the assumption that only thermal effects need be of concern.

In 2015, an appeal to the United Nations and all member states was signed by 206 scientists from 40 countries. The appeal stated that the current safety guidelines/standards are inadequate because they don't take into consideration non-thermal effects. The 206 scientist signers all had published peer reviewed scientific papers on biological effects of EMFs, collectively having published over 2000 such papers.

There should be no question that there is an international scientific consensus on the existence of non-thermal health effects and the inadequacy of safety guidelines/standards.

So how are these non-thermal effects produced?

I stumbled onto the answer that explains most of them in 2012 and have published 5 papers documenting this mechanism:

Pall ML. 2013 Electromagnetic fields act via activation of voltage-gated calcium channels to produce beneficial or adverse effects. J Cell Mol Med 17:958-965.

Pall ML. 2014 Electromagnetic field activation of voltage-gated calcium channels: role in therapeutic effects. Electromagn Biol Med. 2014 Apr 8.

Pall ML. 2015 Scientific evidence contradicts findings and assumptions of Canadian Safety Panel 6: microwaves act through voltage-gated calcium channel activation to induce biological impacts at non-thermal levels, supporting a paradigm shift for microwave/lower frequency electromagnetic field action. Rev Environ Health 30:99-116.

Pall ML. 2015 Microwave frequency electromagnetic fields (EMFs) produce widespread psychiatric effects including depression. J Chem Neuroanatomy, 2015 Aug 21. pii: S0891-0618(15)00059-9. doi: 10.1016/j.jchemneu.2015.08.001. [Epub ahead of print]

Pall ML. 2015 How to approach the challenge of minimizing non-thermal health effects of microwave radiation from electrical devices. International Journal of Innovative Research in Engineering & Management (IJIREM) ISSN: 2350-0557, Volume-2, Issue -5, September 2015; 71-76.

How are the non-thermal effects produced?

26 different studies have shown that the non-thermal effects of microwave/lower frequency EMFs can be blocked or greatly lowered by calcium channel blockers, drugs that are specific for blocking voltage-gated calcium channels (VGCCs).
5 different types of calcium channel blockers were used in these studies, with each having distinct chemical structures and binding to different sites to block channels.

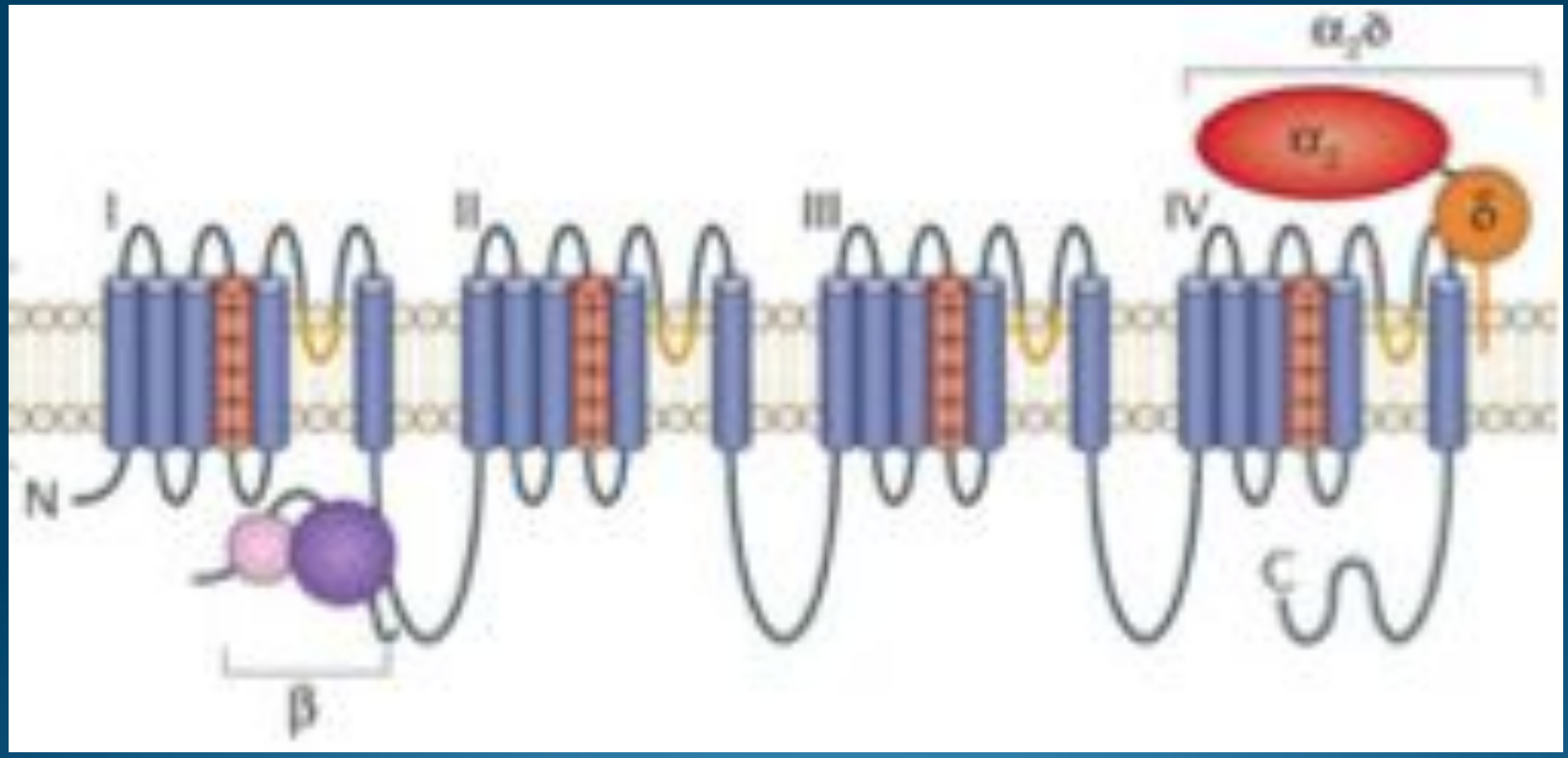
What this shows is that EMFs act by activating the VGCCs, allowing calcium ions (Ca2+) to flow into the cell. Most if not all of the biological effects are produced by excessive calcium in the cell!

Both microwave frequency EMFs and extremely low frequency EMFs (such as from our electrical power lines) act via VGCC activation.

There are 5 different additional types of evidence that each provide further support for the VGCC mechanism of action for non-thermal EMF effects. However we only have time to talk about the most important of these.

The VGCCs and some other voltage-gated ion channels have a structure which causes them to be opened in response to electrical changes, a structure called the voltage sensor. I will argue that the voltage sensor is extraordinarily sensitive of electrical effects of EMFs. For that reason, the voltage sensor is the primary, possibly the sole target of low intensity EMFs.

Industry acknowledges that microwave/lower frequency EMFs put forces on + or - charged groups, but states that the forces produced by these low intensity EMFs are too low to produce biological effects.



Taken from Prof. Annette Dolphin,
Nature Reviews Neuroscience

In comparing the forces on the voltage sensor with the forces on singly charged groups elsewhere in the cell:

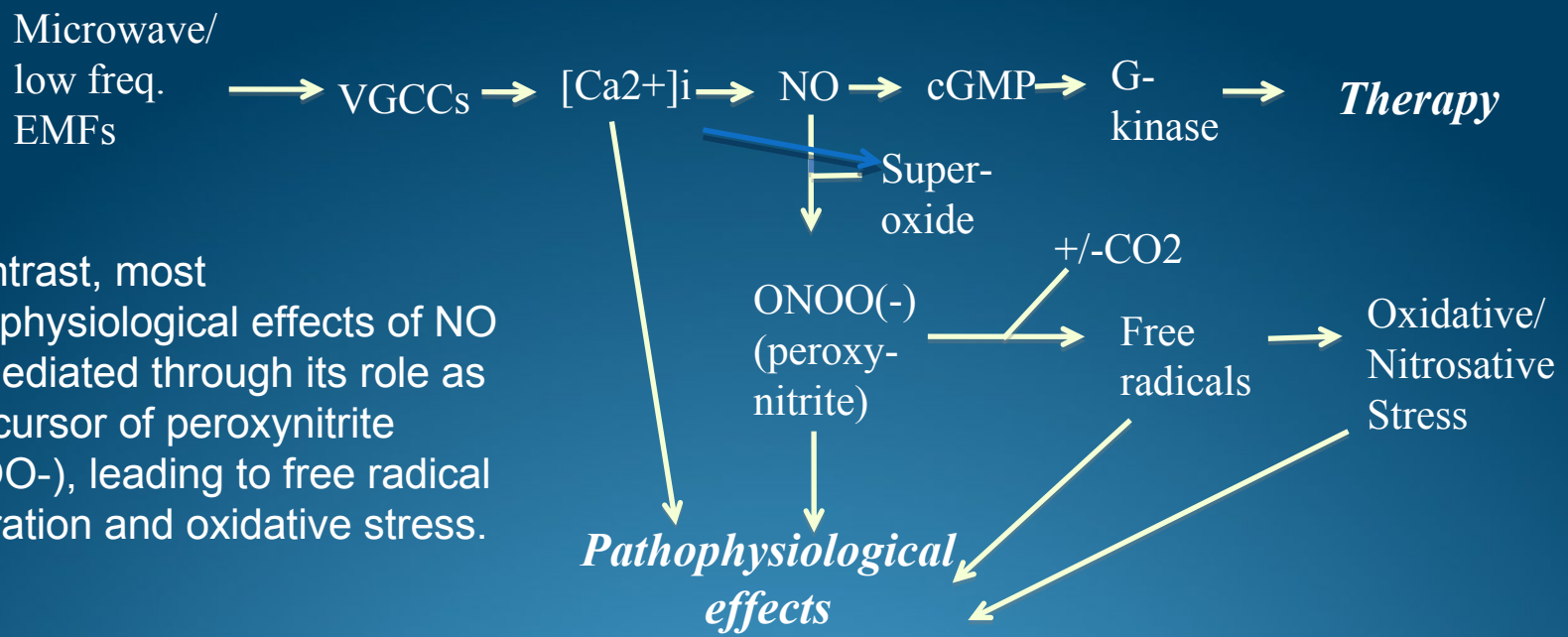
The force on the voltage sensor is:

20 X 120 X 3000 = 7.2 million times stronger

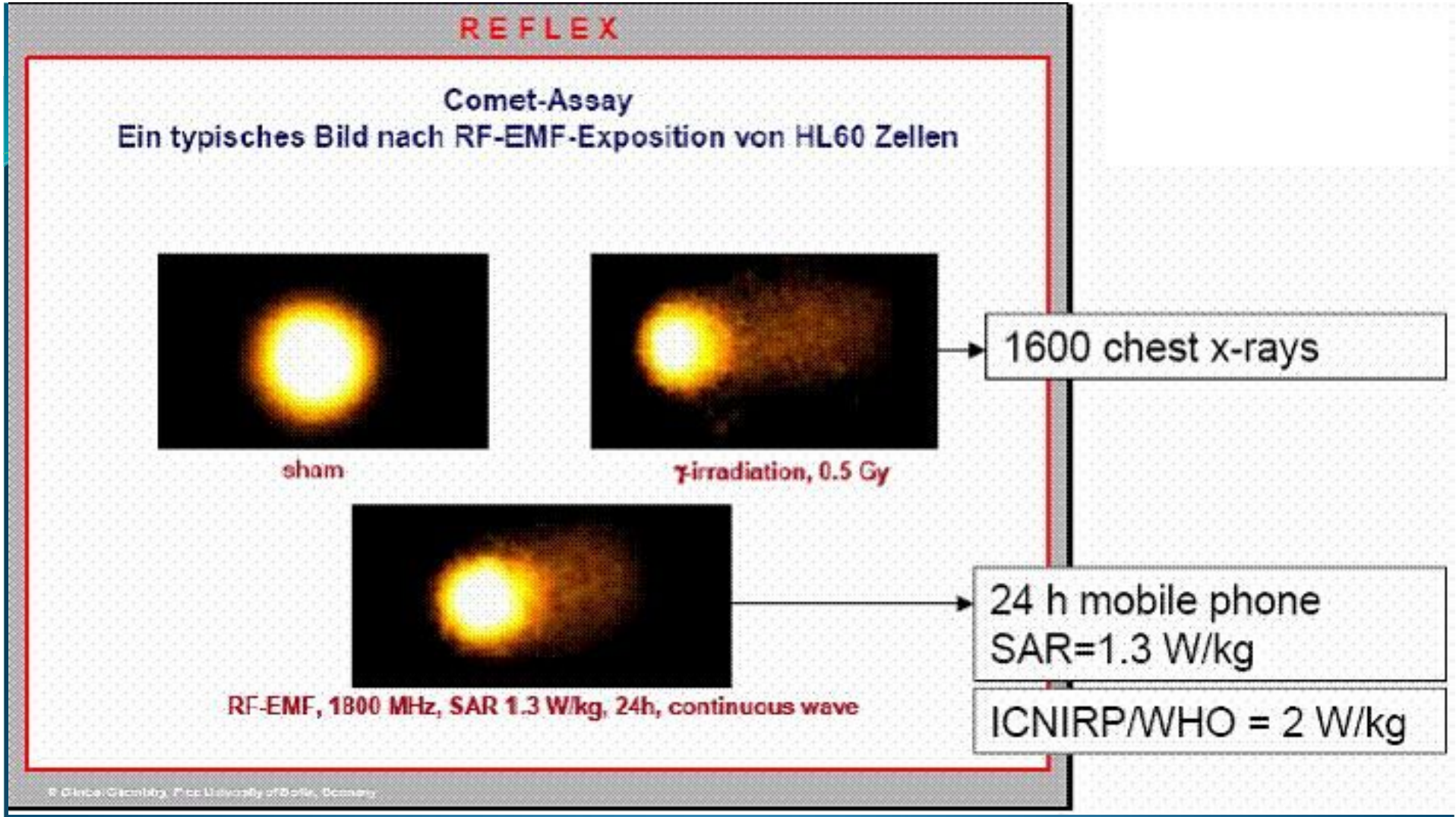
Because EMF heating is produced mainly by forces on singly charged groups in the aqueous phases of the cell, this argues that the safety guidelines/standards allow us to be exposed to EMFs that are 7.2 million times too high!

Most physiological responses to [Ca2+]i and NO, act as follows:

NO increases levels of cGMP, leading in turn to stimulation of the cGMP-dependent protein kinase (protein kinase G).



In contrast, most pathophysiological effects of NO are mediated through its role as a precursor of peroxynitrite (ONOO-), leading to free radical generation and oxidative stress.



J. Lutz and F. Adlekofer, Objections against current limits for micro-wave radiation. WFMN07_II-Ai: 119-123.k

See also: **Non-thermal DNA breakage by mobile-phone radiation (1800 MHz) in human fibroblasts and in transformed GFSH-R17 rat granulosa cells in vitro**

Cancer (cont)	found in inflammatory carcinogenesis
Breakdown of blood-brain barrier	Peroxynitrite-mediated AP-1 activation leads to increased matrix metalloproteinases (MMPs) synthesis leading, in turn, to proteolysis of tight junction proteins
Male and female infertility	Induction of double strand DNA breaks; Other oxidative stress mechanisms; [Ca2+]i mitochondrial effects causing apoptosis; in males, breakdown of blood-testis barrier
Therapeutic effects	Increases in $[Ca]_i$ and NO/NO signaling via protein kinase G
Depression; diverse neuropsychiatric symptoms	VGCC activation of neurotransmitter release; other effects including peroxynitrite pathway; possible role of excess epinephrine/norepinephrine
Melatonin depletion; sleep disruption	VGCCs, elevated $[Ca]_i$ leading to disruption of circadian rhythm entrainment as well as melatonin synthesis
Cataract formation	VGCC activation and $[Ca]_I$ elevation; calcium signaling and also peroxynitrite/oxidative stress action of the proteins of the lens of the eye
Tachycardia, bradycardia, arrhythmia, sometimes leading to sudden cardiac death; also heart palpitations	Very high VGCC activities found in cardiac (sinoatrial node) pacemaker cells; excessive VGCC activity and [Ca2+]i levels produces these electrical changes in the heart; heart palpitations may also involve activation of voltage-gated potassium channels

These are not the only pathophysiological effects of such EMFs but these are among the best understood in terms of mechanism. And they give you some idea of the breadth of the effects seen.

They document how these microwave frequency EMFs attack each of the four things we most value as individuals and as a species:

- Our health
- Our brain function
- The integrity of our genomes
- Our ability to produce healthy offspring

Electromagnetic HyperSensitivity (EHS)

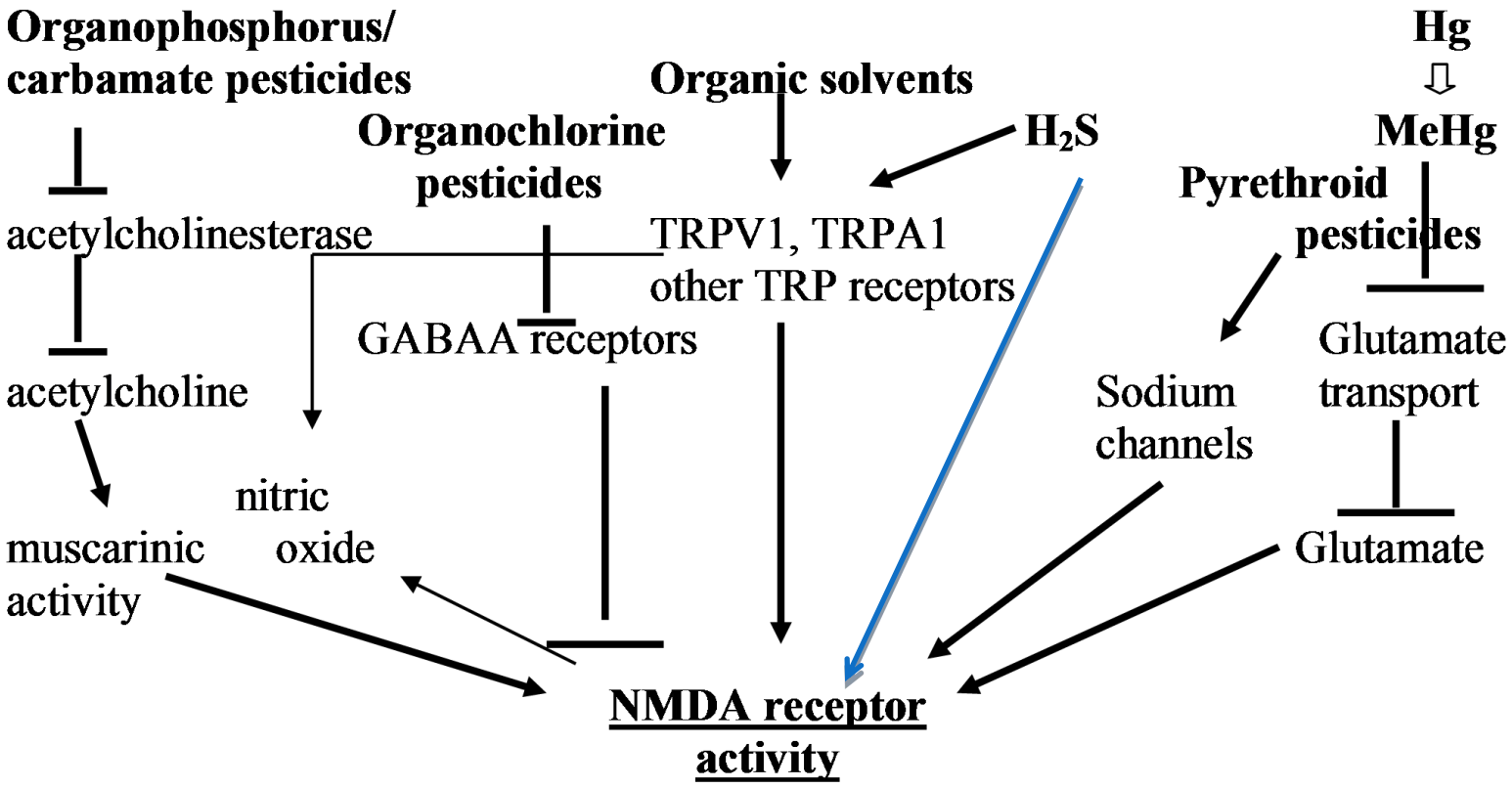
Cases of EHS are thought to be caused by previous exposures to EMFs, particularly microwave / radiofrequency EMFs.

One of the main sources of information on possible mechanism of EHS is what we know about the mechanism of *Multiple Chemical Sensitivity* (MCS):

EHS and MCS have many things in common:

- Cases of each can be initiated by previous exposures
  - of chemicals in the case of MCS, and
  - of EMFs in the case of EHS
- Such exposures can then cause high level sensitivity responses
- MCS and EHS are often comorbid (occurring in the same individuals)
- Both involve symptoms coming from the brain, and symptoms coming from peripheral tissues.
- There is a lot of variation in symptoms from one individual to another
  - This is consistent with a primarily local mechanism with variable tissue distribution

Chemical Action in MCS



Similarities between the NMDA receptors and the L-type VGCCs:

Both channels

- Open up an ion channel when activated.
- Stay open a relatively long time period compared with other channels.
- Allow substantial amounts of calcium to flow into the cell.
- Create their effects through excessive intracellular calcium [Ca2+]i.
- Lead to the production of large amounts of NO, due to the action of two calcium-dependent NO synthases, with the NO often leading to production of peroxynitrite.
- Have been shown to be able to stimulate *long-term potentiation*, i.e. the process in the central nervous system involved in learning and memory by *neural sensitization*.

Propositions:

- *All of these related similarities have roles in allowing each of them to produce the high level sensitivities that we call MCS and EHS.*
- *The similar properties of the NMDA receptors and the L-type VGCCs are almost certainly behind these two types of sensitivity.*

Two other types of observations that suggest EHS is a real sensitivity condition:

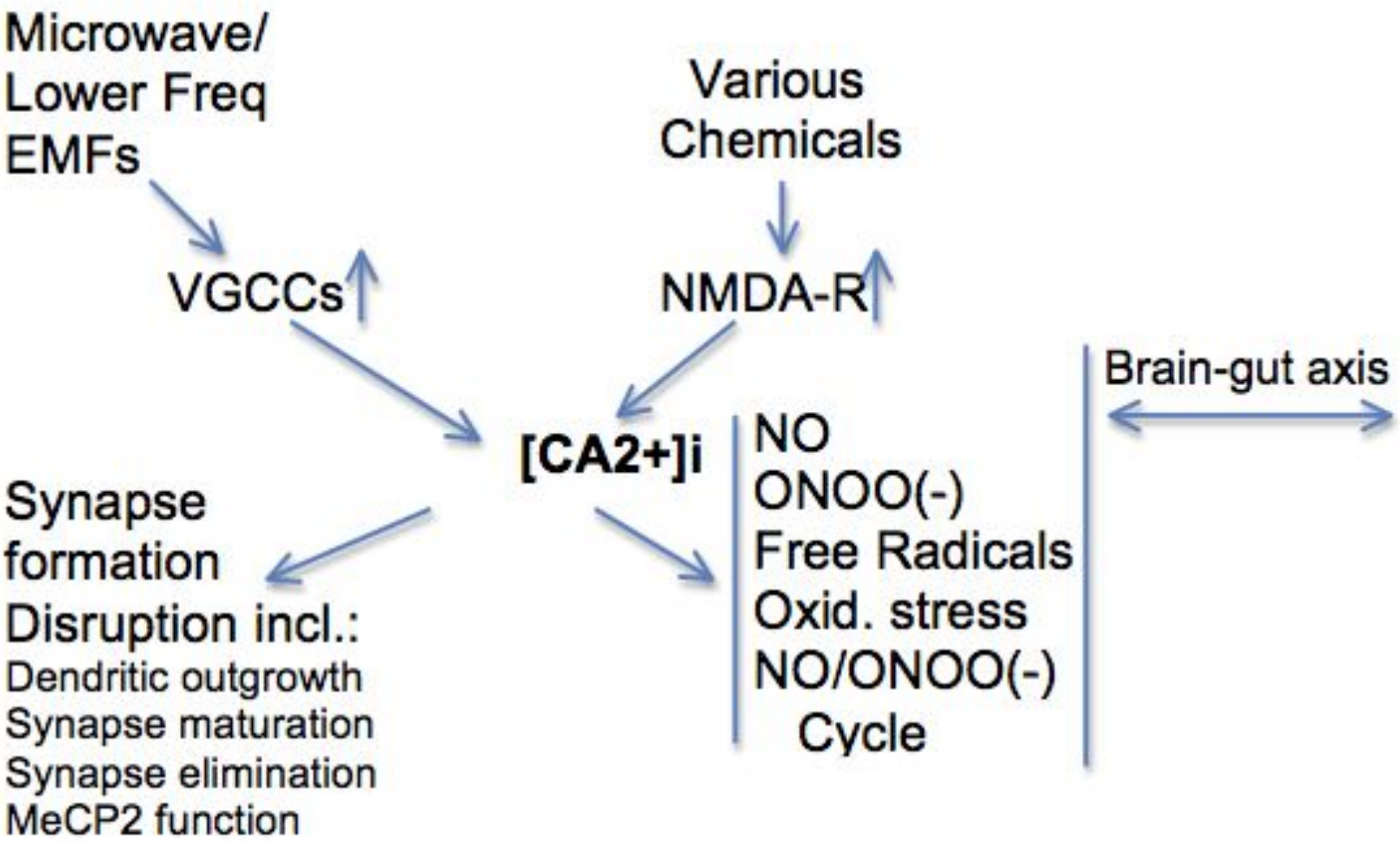
1. EHS people on exposure often develop neuropsychiatric symptoms similar to those caused by EMF exposure in the general population – just a much lower intensities.
2. They also can develop cardiac symptoms similar those produced by EMF exposures – again at much lower intensities.

Dr. Cornelia Waldmann-Selsam (in Germany) has described a woman with EHS who has lost her parathyroid function due to an accident – greatly impaired ability to regulate blood calcium levels.
Given me permission to talk about this.

When the EHS woman is exposed to extremely low levels of EMF exposure – such as from out in the forest where she lives – hikers walk somewhere not too far away – use cell phone – she reacts to it. Her blood levels of calcium drop dramatically to well below normal.
Interpretation: Her VGCCs are highly sensitive to EMFs, such that very low intensity EMFs lead to vast calcium influx into cells, thus greatly lowering blood calcium. Argues that her VGCCs are extremely sensitive to EMFs.

While there are many things of concern here, there are still worse things that may be in store for us – what may be called worse case scenarios! I'll talk about 5 of these.

Worst case scenario number 1:
The autism epidemic is probably largely caused by EMF exposures (although chemicals also have a role). At the AutismOne meeting Chicago, last year, I discussed 32 different types of evidence that support a pathway of action from microwave EMF exposure through disruption of synapse development in the developing brain of autism patients.


Microwave/
Lower Freq
EMFs
Various
Chemicals
VGCCs
NMDA-R
[CA2+]i
Brain-gut axis
NO
ONOO(-)
Free Radicals
Oxid. stress
NO/ONOO(-)
Cycle
Synapse
formation
Disruption incl.:
Dendritic outgrowth
Synapse maturation
Synapse elimination
MeCP2 function

Worst case scenario number 2:
Neuropsychiatric effects of the microwave EMF exposures

Worst case scenario number 3:
Sterility and spontaneous abortion, reproduction goes to zero

We know that male and female infertility are increasing as is spontaneous abortion and we know that these can each be caused by microwave EMFs.

Magras and Xenos (Bioelectromagnetics 1997;18:455-461) showed that pairs of mice mated at two exposure levels near and “antenna park” of large numbers of broadcasting antennae (but still within safety standards) went through only two (higher exposure) or four matings (lower exposure) in less than 5 months before they became completely sterile.

Worst case scenario number 4:
Huge numbers of germ line mutations.

We know that:
1.Microwave fields are genotoxic – produce widespread DNA damage in cells.
2.Germ line cells are heavily impacted by these EMFs.
3.There have been only 3 studies of mutations in germ line cells following microwave/RF EMF exposures, to my knowledge (all 3 in males), with each of the 3 reporting mutational increases: Sarkar et al, Mutat Res 1994;320:141-147; Aitken et al, In J Androl 2005;28:171-179; De Iuliis et al, PloS One 2009;4(7) e6446

We could be destroying our biological inheritance.

Worst case scenario number 5:

Epidemic of premature Alzheimer's disease. We are seeing an unexplained epidemic of premature Alzheimer's and other early onset dementias. We know that:

- Early onset neurodegenerative diseases are increasing rapidly- suggested to be caused by microwave EMF exposures (MkKie, Brain Diseases Affecting More People and Starting Earlier than Ever Before, Science Daily, May 10, 2013).
- Epidemiological studies have shown that occupational exposures to extremely low frequency EMFs, such as from our power lines, increases Alzheimer's incidence. Also know that extremely low frequency EMFs act like microwave EMFs – both act via VGCC activation!
- High levels [Ca2+]i have important roles in Alzheimer's. See especially Celsi et al, Mitochondria, calcium and cell death: A deadly triad in neurodegeneration. Biochim Biophys Acta 2009;1787:335-344.
- Higher VGCC activity, produced by genetic polymorphism, associated with Alzheimer's (Hum Genet 2014;133:85-93).
- Jiang et al showed that young rats exposed to multiple short pulsed microwave EMFs, developed oxidative stress, high amyloid beta (Aβ protein) levels as well as cognitive and memory impairment in middle age – Alzheimer's like changes.
- Electromagnetic pulse exposure induces overexpression of beta amyloid protein in rats. Arch Med Res. 2013 Apr;44(3):178-84. 900 MHz microwave exposures (Electromagn Biol Med. 2012 Mar;31(1):67-74) caused increases brain Aβ protein and oxidative stress.
- Alzheimer's typically has very long latency periods – 20, 25 or 30 years from the time the process starts until symptoms become apparent.

What do we need to do?

- Repeal the 1996 telecommunications act.

- Stop these ever increasing levels of exposures. There are many ways to make these devices much safer but we are running as fast as we can in exactly the wrong direction.

- We need biologically relevant safety standards, not the nonsense safety standards that we have now. The best way to develop such standards is to study the effects of EMFs on cells in culture, cells that have high levels of various types of VGCCs. Such cell culture work is not difficult to do, nor is it very expensive to do – it needs to be started right now!!