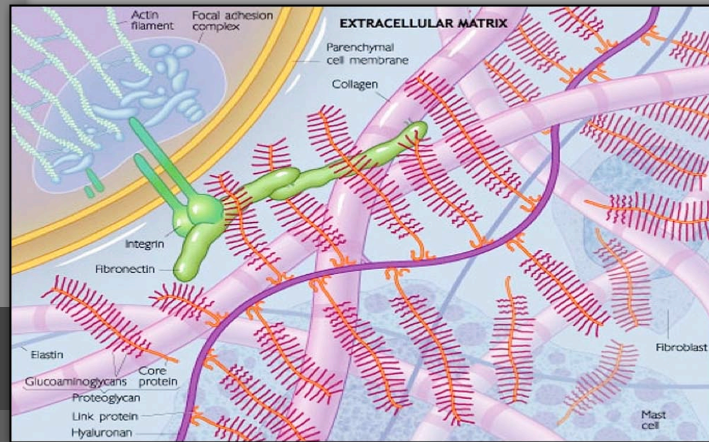
Microwave RF Interacts with Molecular Structures



(Original art by Raychel Ciemma, Springfield, Oregon, for Paul Lee DO FAAO's book Interface, used with permission.)

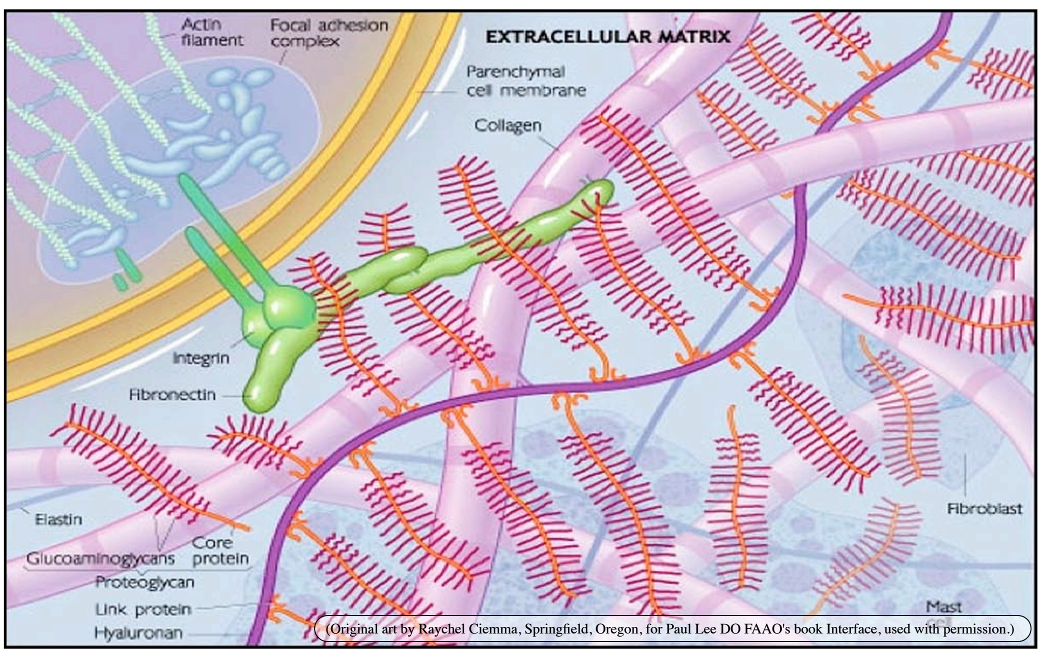
The molecules in our bodies vary in size and in total electric charge.

These molecular structures of our body can resonate with fluctuating electromagnetic fields.

Any charged particle has a resonant frequency.

This frequency varies depending on the total mass and charge of the particle.

Molecules resonate in fluctuating electromagnetic fields.



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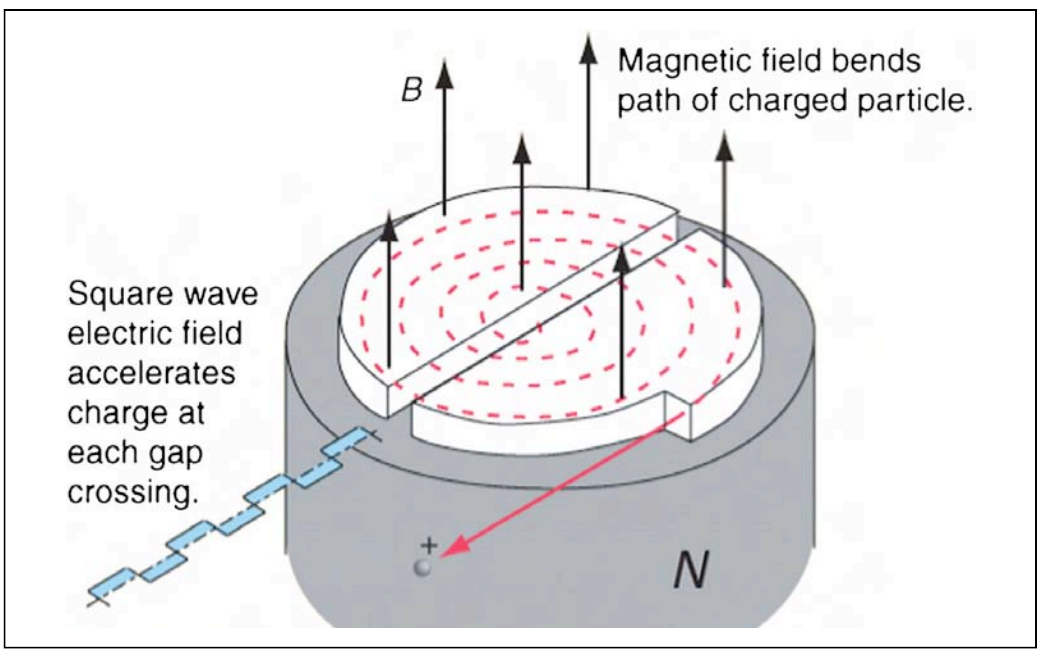
The molecules in our bodies vary in size and total electric charge.

These molecular structures of our body resonate with fluctuating electromagnetic fields.

Resonance Frequency

When you push something at its resonant frequency,
a small force can produce a lot of motion.

Resonance Frequency

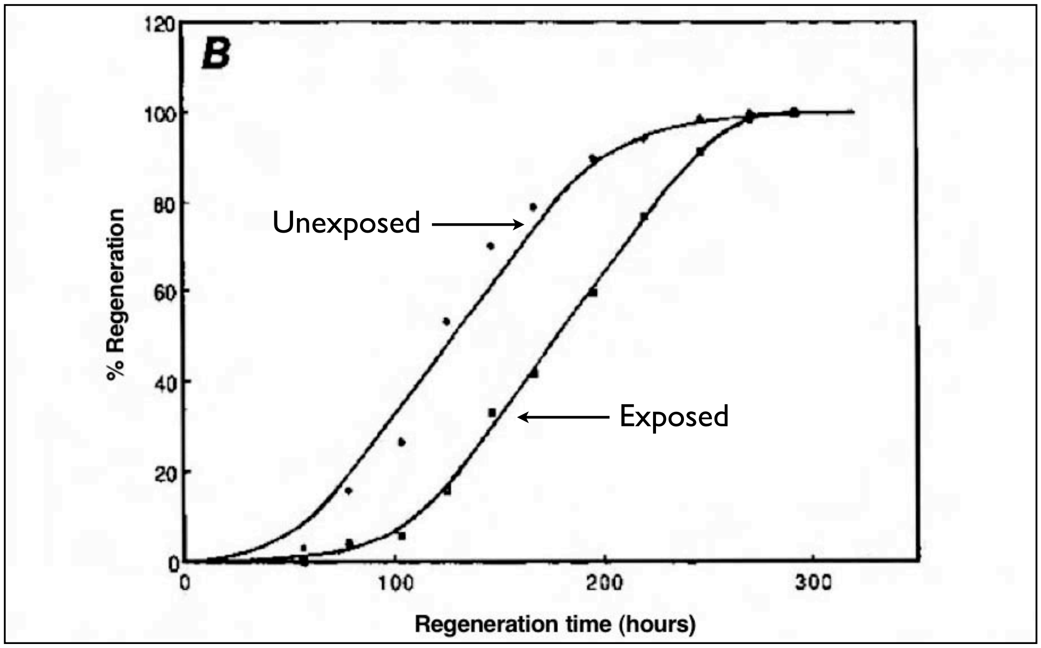


Placing the particle in an electromagnetic field that fluctuates at the resonant frequency will amplify the motion of the particle.

This is how a cyclotron works, and the frequency is often referred to as the "Ion Cyclotron Resonance" or ICR frequency.

Magnetic fields that fluctuate at the resonant frequency of an ion like calcium, or of a specific enzyme, can have dramatic effects on biochemical processes in the body.

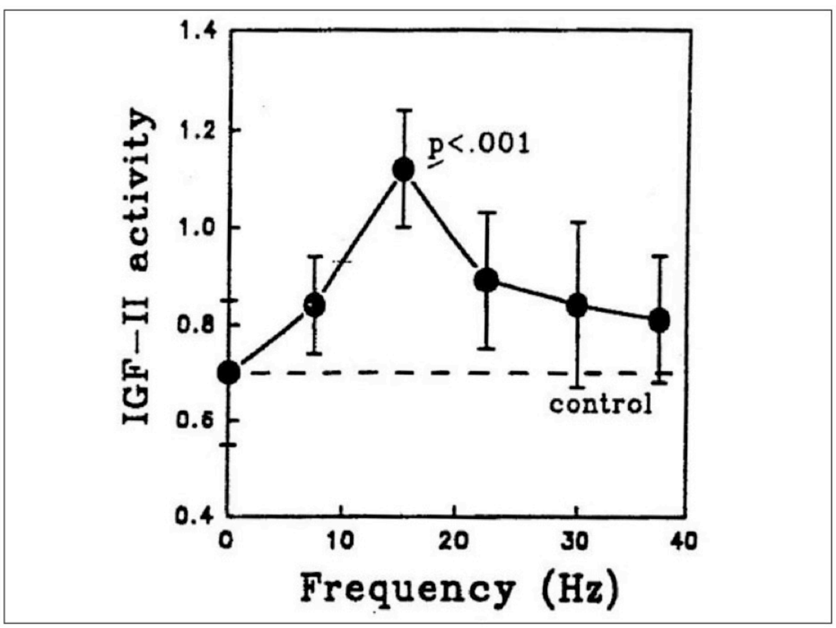
Resonance Effect



Planaria exposed to a magnetic field fluctuating at the calcium ion's ICR frequency take far longer (48 hours) to regenerate than those that are not exposed.

Liboff A. Weak low-frequency electromagnetic fields are biologically interactive. In: Giuliani L, Soffritti M, eds. Non-Thermal Effects and Mechanisms of Interaction Between Electromagnetic Fields and Living Matter -- An ICEMS Monograph. Fidenza, Italy: Mattioli, (2010): 51-61. *http://www.ramazzini.it/ricerca/publications.asp*

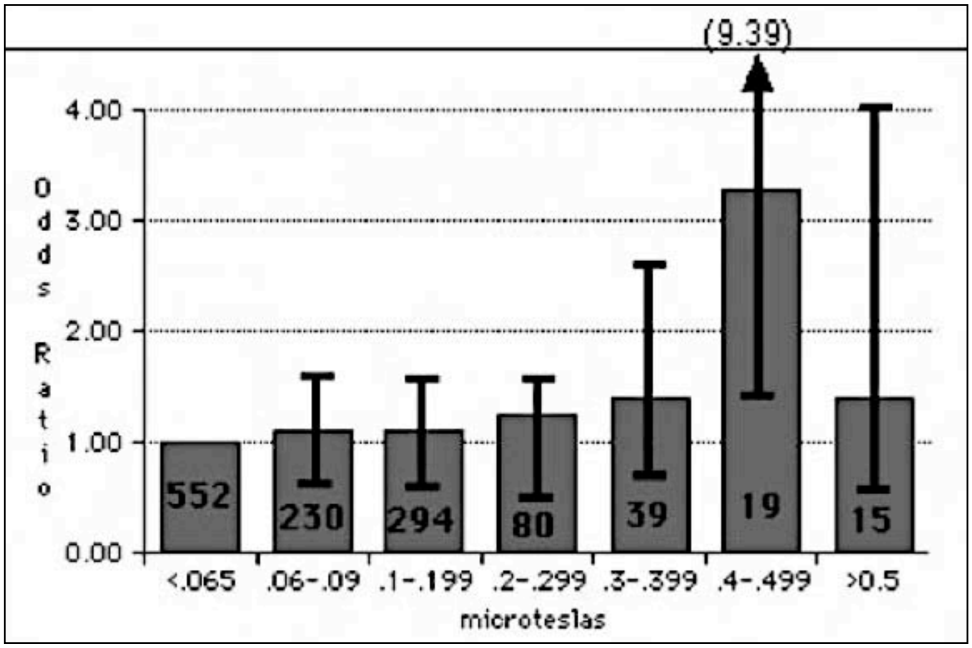
"frequency window"



Some effects of fluctuating EMF occur at specific frequencies, called "frequency windows".
The peak in IGF-II expression for human osteosarcoma bone cells exposed to combined magnetic fields occurs when the field is tuned to the calcium ion's ICR frequency

Liboff A. Weak low-frequency electromagnetic fields are biologically interactive. In: Giuliani L, Soffritti M, eds. Non-Thermal Effects and Mechanisms of Interaction Between Electromagnetic Fields and Living Matter -- An ICEMS Monograph. Fidenza, Italy: Mattioli, (2010): 51-61. *http://www.ramazzini.it/ricerca/publications.asp*

"power window"



At a given frequency, some power levels may have a different effect than others. This is a "power window"

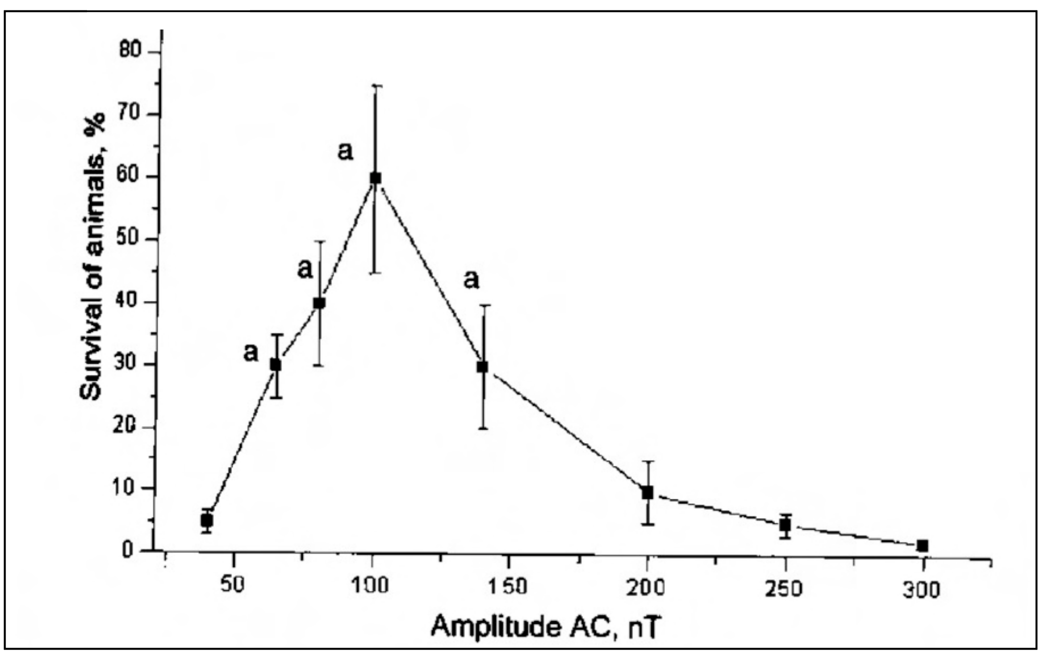
In this illustration, the odds ratio for childhood onset of Acute Lymphoblastic Leukemia is significantly higher if they are exposed to 60 cycle magnetic fields at a magnitude of 0.4 to 0.499 microtesla.

Lower and higher field magnitudes do not show the same effect.

Liboff A. Weak low-frequency electromagnetic fields are biologically interactive. In: Giuliani L, Soffritti M, eds. Non-Thermal Effects and Mechanisms of Interaction Between Electromagnetic Fields and Living Matter -- An ICEMS Monograph. Fidenza, Italy: Mattioli, (2010): 51-61. *http://www.ramazzini.it/ricerca/publications.asp*

Fig. 1. Odds ratios for childhood ALL, determined by Linet et al 6, as a function of residential magnetic field. The large ratios seen for fields between .4 and .499 µT, although having many less participants, are nevertheless statistically significant

"power window"



Mice with Ascites Ehrlich carcinoma 33,

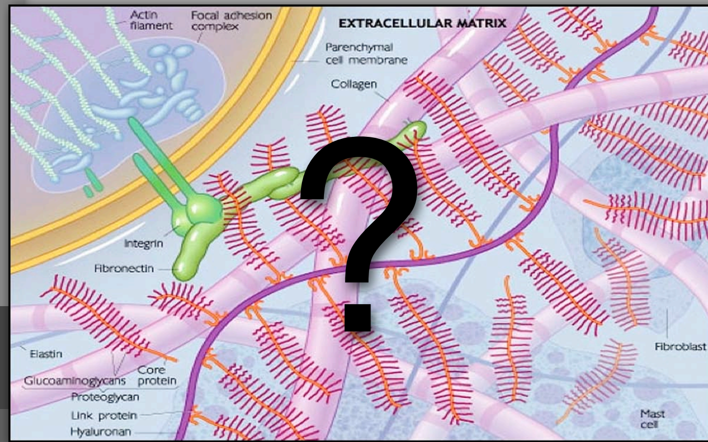
exposed to a fluctuating EM field tuned to the ICR frequency for aspartic acid and glutamic acid ions.

Survival varies with the AMPLITUDE (magnitude) of the field.

Liboff A. Weak low-frequency electromagnetic fields are biologically interactive. In: Giuliani L, Soffritti M, eds. Non-Thermal Effects and Mechanisms of Interaction Between Electromagnetic Fields and Living Matter -- An ICEMS Monograph. Fidenza, Italy: Mattioli, (2010): 51-61. *http://www.ramazzini.it/ricerca/publications.asp*

Fig. 5. Survival curve for mice infected with Ascites Ehrlich carcinoma33, under ICR conditions corresponding to mean tuning (4.4 Hz) for aspartic acid and glutamic acid ions. In contrast to Fig. 2 where the frequency is varied, a resonance (or window) peak is observed as the AC magnetic field intensity is varied

What does this mean?



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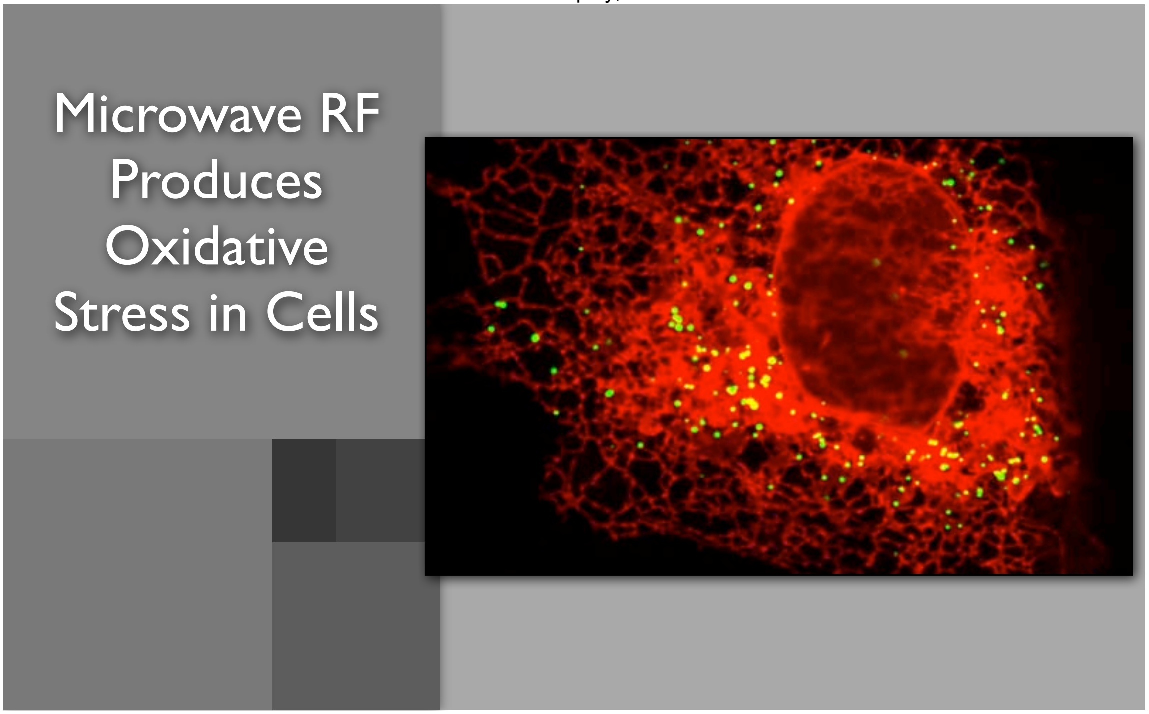
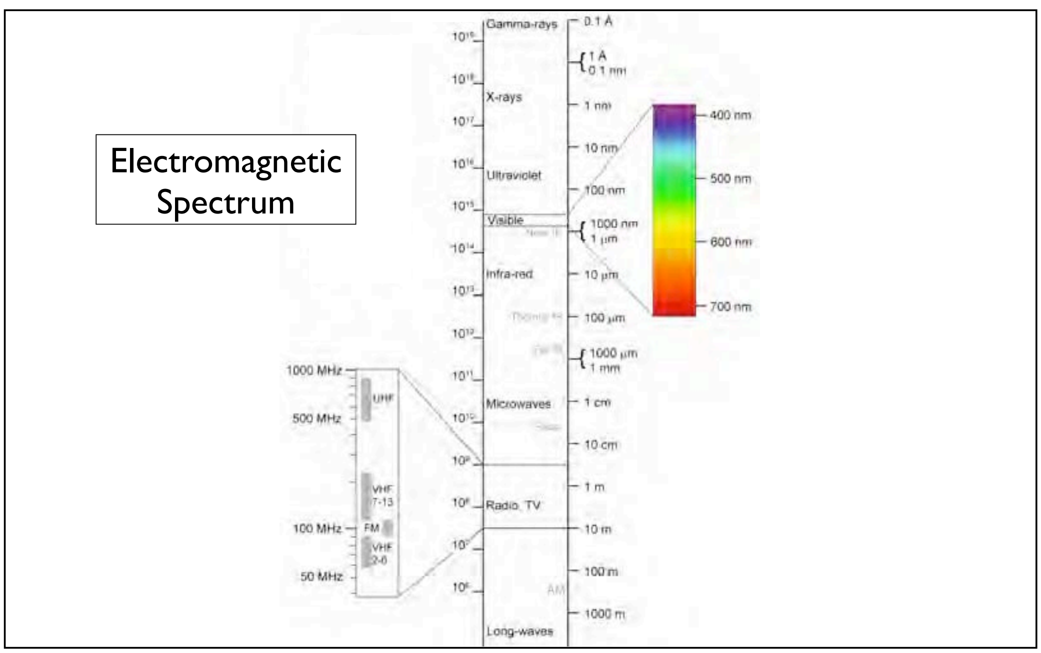
There are thousands of enzymes and other molecules in the human body.

Each has its own mass, charge, and resonant frequency.

This means that different electromagnetic frequencies will resonate with different molecules.

Which means that the biological effects of EMF on molecular physiology are probably much more complex than is generally assumed to be the case.





Ionizing radiation from the high energy end of the electromagnetic spectrum can directly break DNA molecular bonds, causing mutations.

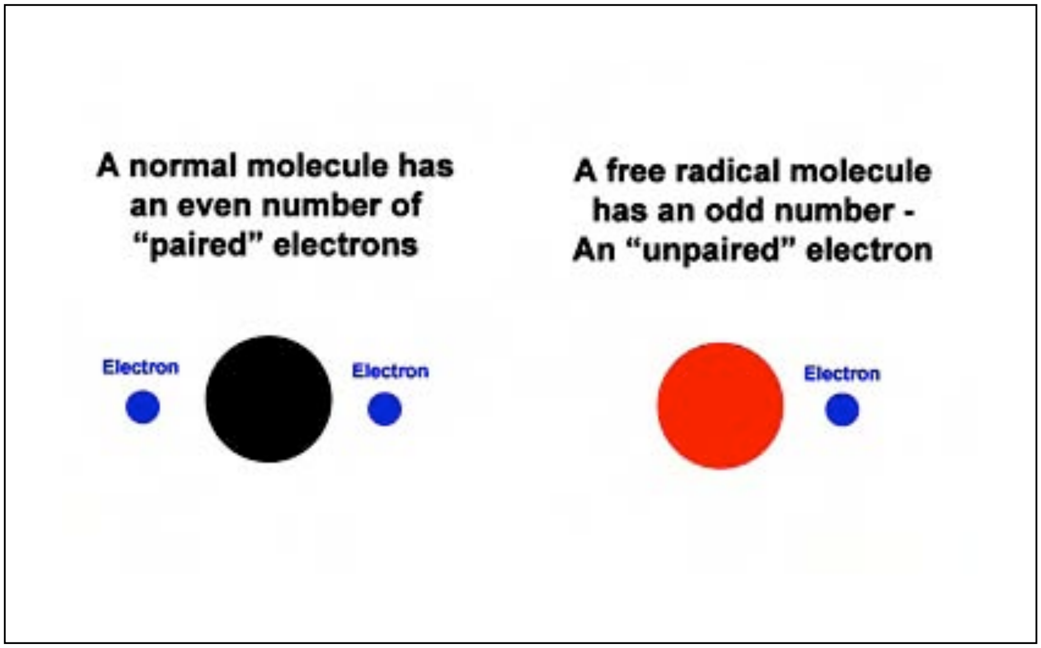
But photons of microwave RF do not have enough energy to directly break covalent molecular bonds.

Industry advocates often make the statement that since RF cannot break molecular bonds, there is no way that it can cause cancer.

Such statements sound like good physics. But they reflect a poor understanding of biology.

Tobacco can cause cancer. Genital warts can cause cancer. Asbestos can cause cancer. There are many ways to cause cancer besides ionizing radiation.

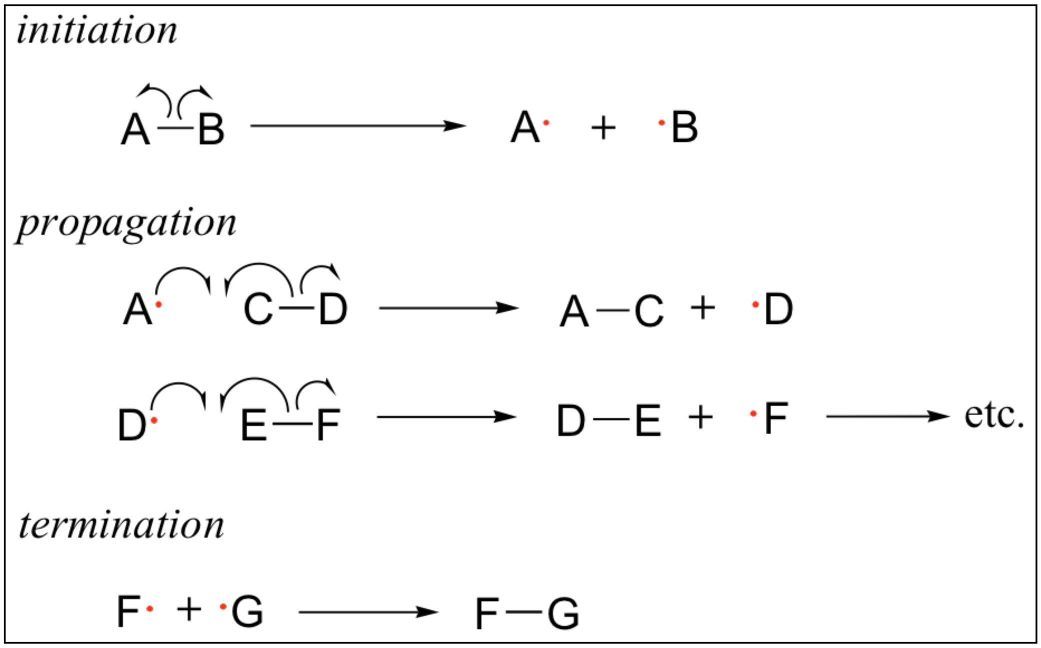
Free Radicals



Free radicals are oxidizing agents.

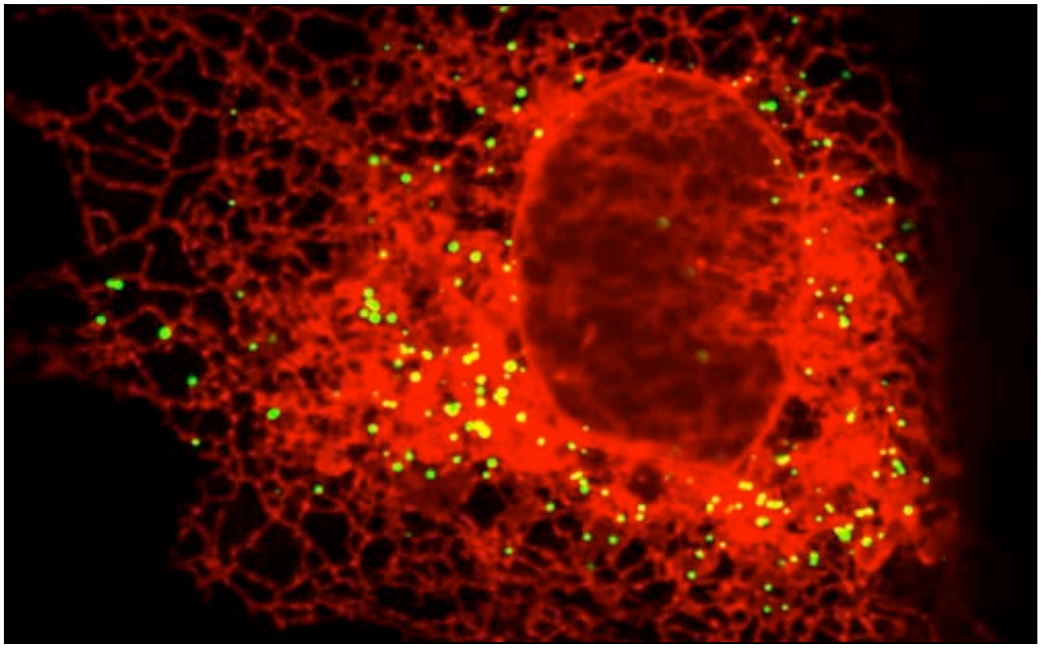
They take electrons from other atoms or molecules, which can break molecular bonds.

Life cycle of a free radical.



Precursor molecule (AB) splits to form two free radicals.

Free radicals then can produce chain reactions, causing oxidative damage.



Peroxizomes (yellow) in a cell – packages of free radicals stored in cells.

Cells are making free radicals all the time.
Our bodies release them in inflammation to combat bacteria, remove diseased tissue, etc.
The free radicals release by the inflammatory process can break covalent bonds and fragment macomolecules.

Review Article *J. Cell. Mol. Med. Vol XX, No X, 2013 pp. 1-9*

Guest Editor:

Electromagnetic fields act *via* activation of voltage-gated calcium channels to produce beneficial or adverse effects

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Received: January 8, 2013; Accepted: May 20, 2013

Abstract

The direct targets of extremely low and microwave frequency range electromagnetic fields (EMFs) in producing non-thermal effects have not been clearly established. However, studies in the literature, reviewed here, provide substantial support for such direct targets. Twenty-three studies have shown that voltage-gated calcium channels (VGCCs) produce these and other EMF effects, such that the L-type or other VGCC blockers block or greatly lower diverse EMF effects. Furthermore, the voltage-gated properties of these channels may provide biophysically

This recently published article reviews published evidence that EMF can produce physiologic effects by altering the function of voltage gated calcium channels in cell walls.

Pall ML. Electromagnetic fields act via activation of voltage-gated calcium channels to produce beneficial or adverse effects. *J Cell Mol Med* (2013);

Table 1 EMF responses blocked or lowered by calcium channel blockers

Ref. no.	EMF type	Calcium channel	Cell type or organism	Response measured
2	Pulsed magnetic fields	L-type	Human lymphocytes	Cell proliferation; cytokine production
3	Static magnetic field (0.1 T)	L-type	Human polymorphonuclear leucocytes	Cell migration; degranulation
5	ELF	L-type	Rat chromaffin cells	Differentiation; catecholamine release
6	Electric field	L-type	Rat and mouse bone cells	Increased Ca^{2+}, phospholipase A2, PGE2
7	50 Hz	L-type	Mytilus (mussel) immunocytes	Reduced shape change, cytotoxicity
8	50 Hz	L-type	AtT20 D16V, mouse pituitary corticotrope-derived	Ca^{2+} increase; cell morphology, premature differentiation
9	50 Hz	L-type	Neural stem/progenitor cells	*In vitro* differentiation, neurogenesis
10	Static magnetic field	L-type	Rat	Reduction in oedema formation
11	NMR	L-type	Tumour cells	Synergistic effect of EMF on anti-tumour drug toxicity
12	Static magnetic field	L-type	Myelomonocytic U937 cells	Ca^{2+} influx into cells and anti-apoptotic effects
13	60 Hz	L-type	Mouse	Hyperalgesic response to exposure
14	Single nanosecond electric pulse	L-type	Bovine chromaffin cells	Very rapid increase in intracellular Ca^{2+}

These are some of the 23 published studies documenting that EMF can increase flow through these calcium channels, producing biological effects.

In all these studies, the effects of EMF on increased cellular calcium levels could be blocked by calcium channel blocking drugs.

Pall ML. Electromagnetic fields act via activation of voltage-gated calcium channels to produce beneficial or adverse effects. *J Cell Mol Med* (2013);

15	Biphasic electric current	L-type	Human mesenchymal stromal cells	Osteoblast differentiation and cytokine production
16	DC & AC magnetic fields	L-type	β-cells of pancreas, patch clamped	Ca^{2+} flux into cells
17	50 Hz	L-type	Rat pituitary cells	Ca^{2+} flux into cells
18	50 Hz	L-type, N-type	Human neuroblastoma IMR32 and rat pituitary GH3 cells	Anti-apoptotic activity
19	Nanosecond pulse	L-type, N-type, P/Q-type	Bovine chromaffin cells	Ca^{2+} dynamics of cells
20	50 Hz	Not determined	Rat dorsal root ganglion cells	Firing frequency of cells
21	700–1100 MHz	N-type	Stem cell–derived neuronal cells	Ca^{2+} dynamics of cells
22	Very weak electrical fields	T-type	Sharks	Detection of very weak magnetic fields in the ocean
23	Short electric pulses	L-type	Human eye	Effect on electro-oculogram
24	Weak static magnetic field	L-type	Rabbit	Baroreflex sensitivity
25	Weak electric fields	T-type	Neutrophils	Electrical and ion dynamics
26	Static electric fields, 'capacitive'	L-type	Bovine articular chondrocytes	Agrican & type II collagen expression; calcineurin and other Ca^{2+}/calmodulin responses

EMF: electromagnetic field; ELF: extremely low frequency.

In all these studies, the effects of EMF on increased cellular calcium levels could be blocked by calcium channel blocking drugs.

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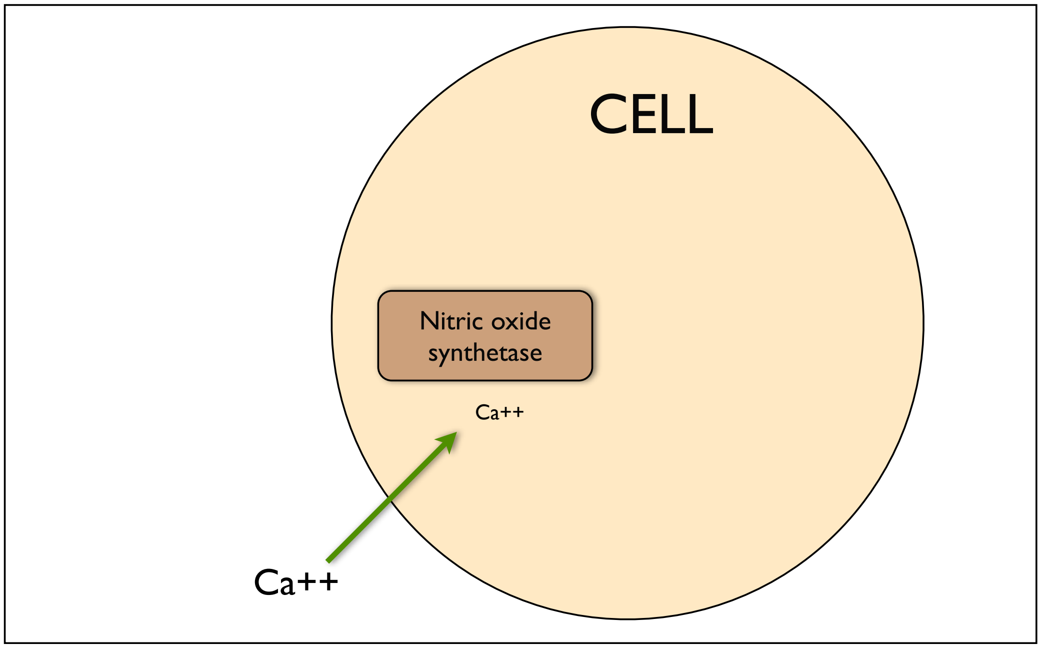
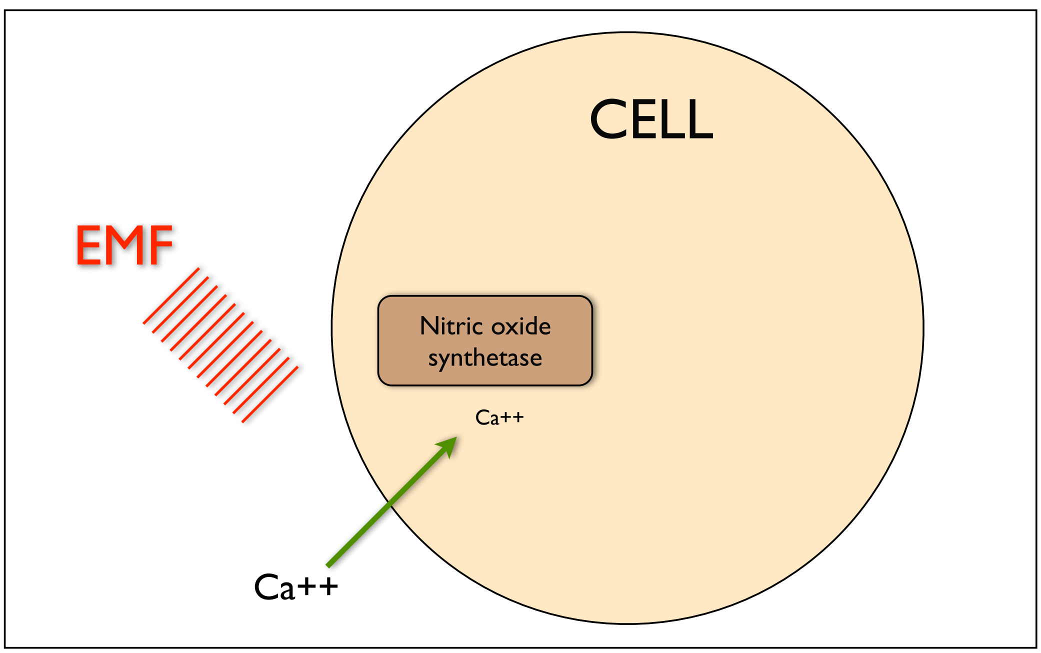
EMF Activation of VGCCs Increases Free Radical Production



Normally, Calcium concentrations are much higher outside of cells than inside them.
Influxes of calcium into cells act as chemical signals to alter cellular physiologic activity.
Here we have a diagram of a cell, with high levels of calcium outside, and lower levels of calcium inside.
The green arrow is a voltage-gated calcium channel, that can open to allow more calcium to enter the cell.
Inside the cell, we can see an enzyme (nitric oxide synthetase).

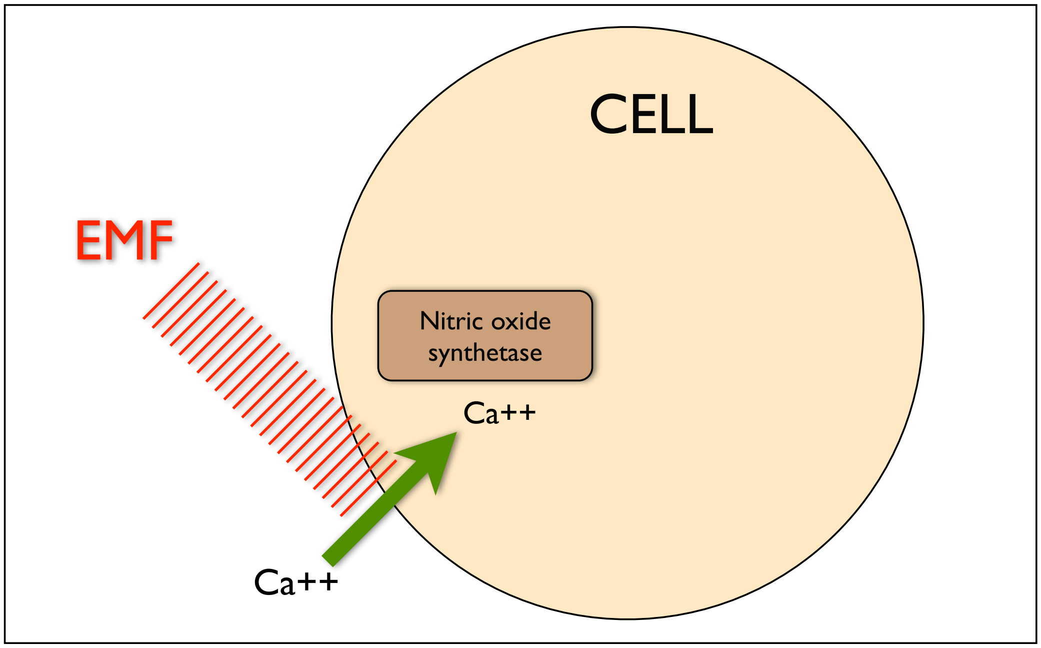
As discussed by Pall ML. Electromagnetic fields act via activation of voltage-gated calcium channels to produce beneficial or adverse effects. *J Cell Mol Med* (2013);

EMF Activation of VGCCs Increases Free Radical Production



An electromagnetic field arrives at the cell wall.

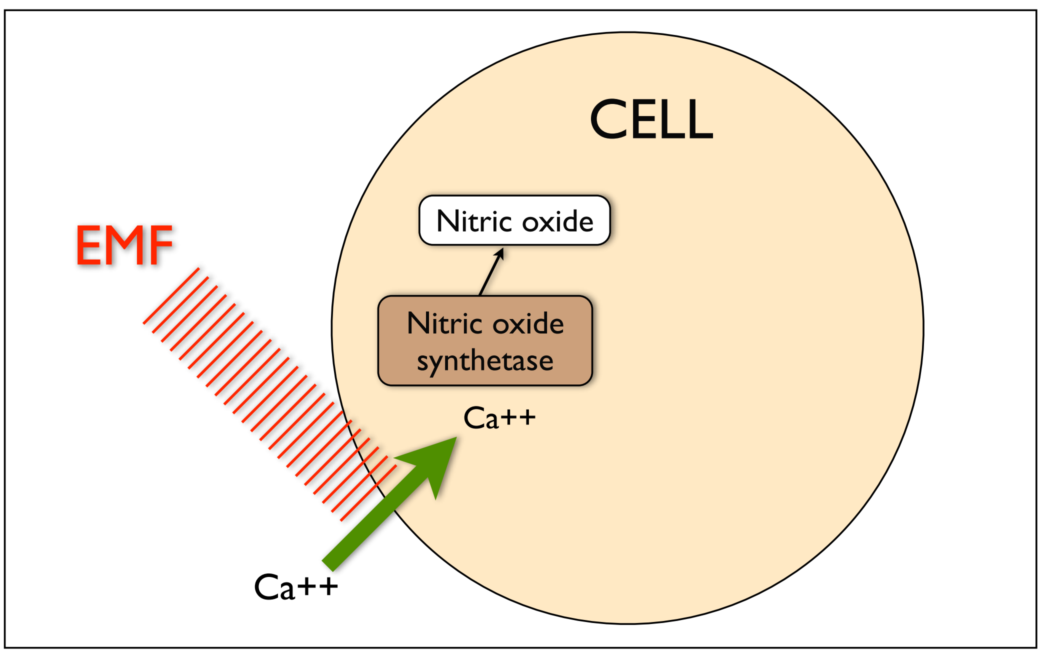
EMF Activation of VGCCs Increases Free Radical Production



The electromagnetic field stimulates opening of voltage-gated calcium channels (VGCCs) in the cell membrane.

This increases Ca++ entry into the cell.

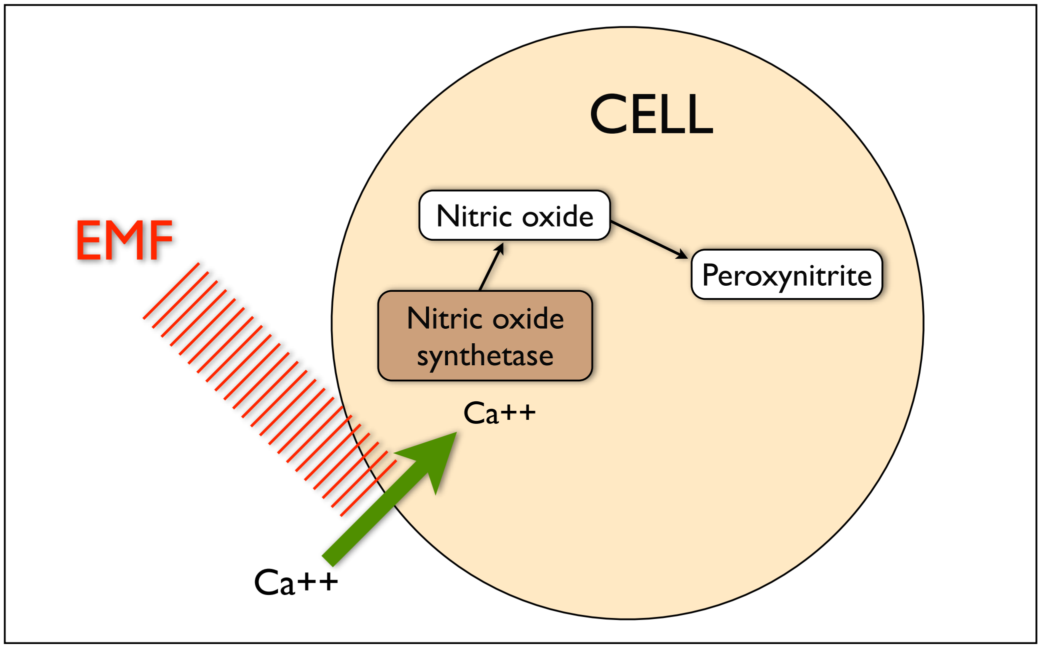
EMF Activation of VGCCs Increases Free Radical Production



Increased intracellular calcium levels stimulate the activity of nitric oxide synthetase,

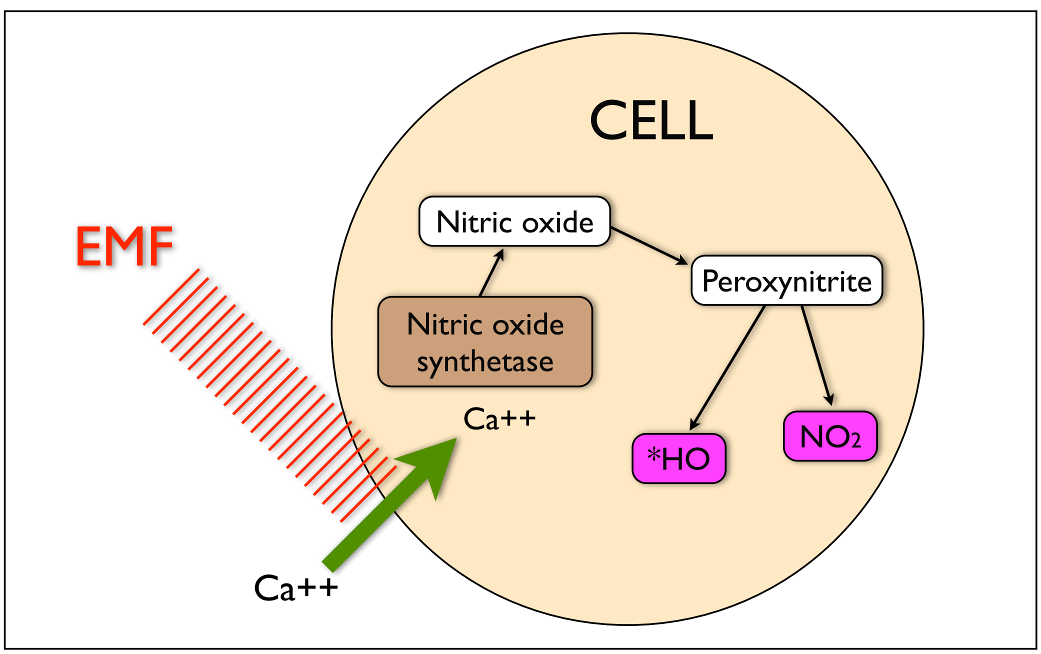
Which leads to increased production of nitric oxide in the cell.

EMF Activation of VGCCs Increases Free Radical Production



Increased nitric oxide leads to increase in peroxynitrite, a potent non-radical oxidant.

EMF Activation of VGCCs Increases Free Radical Production

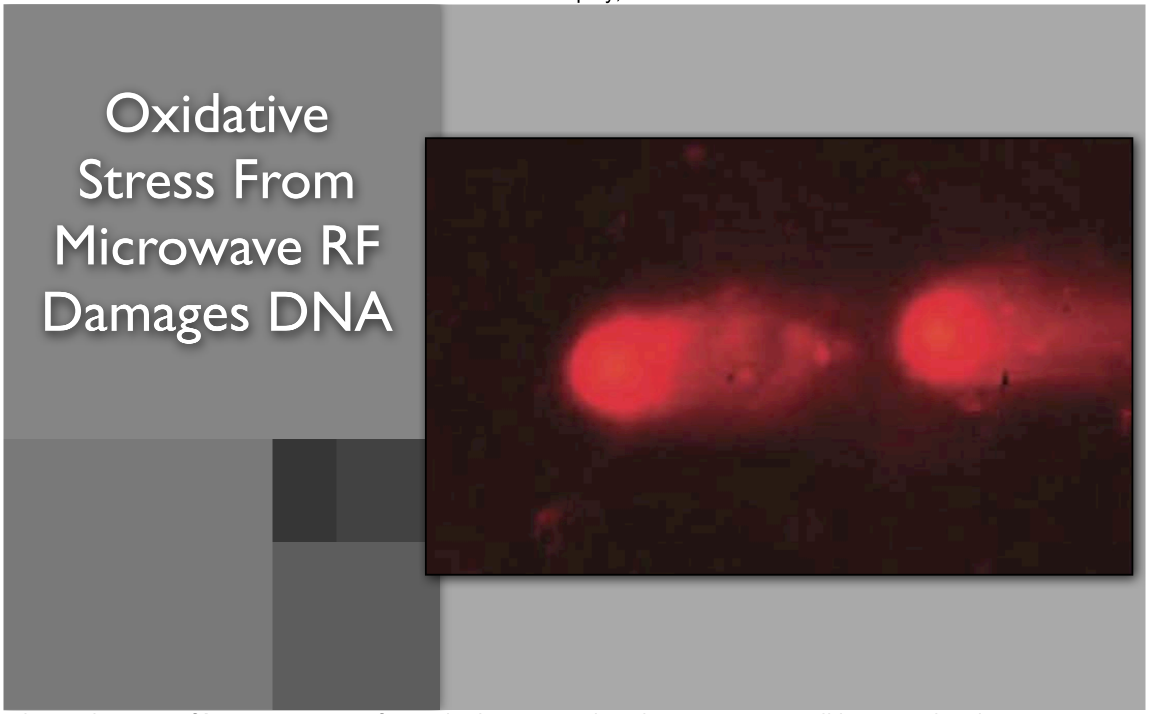


Peroxynitrite produces free radicals, including hydroxyl radical and NO_2.

This increase in free radicals then leads to inflammation, oxidant stress, and damage to cell structures, including DNA.

The EMF doesn't directly damage the cell. It just deranges cellular metabolism.

The free radicals that are produced by this change in metabolism are what causes the damage.

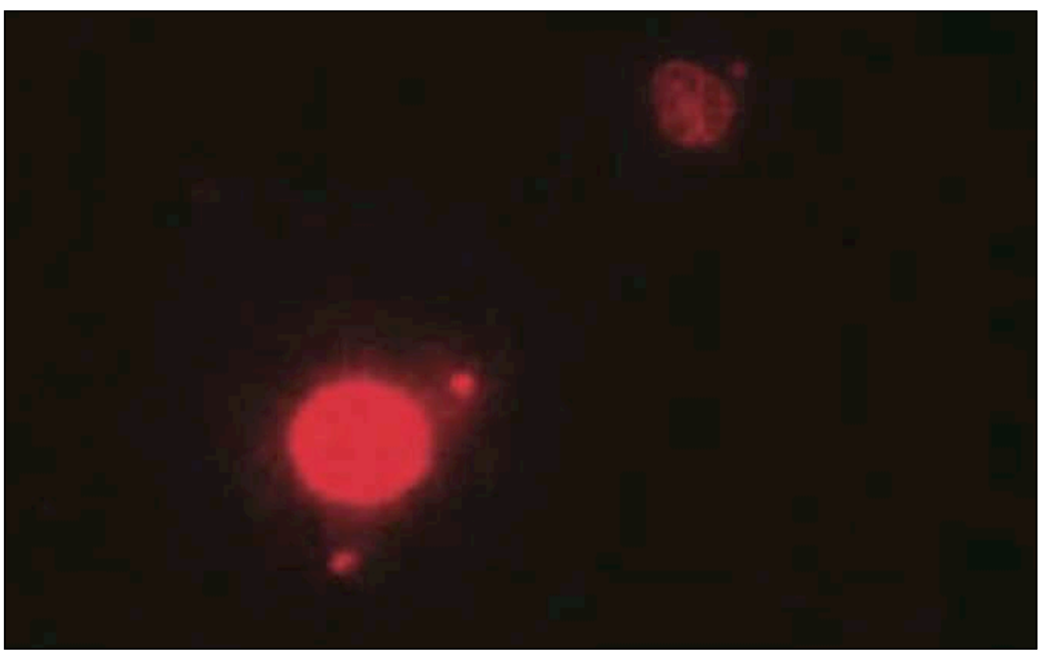


The mechanisms of **how** RF increases free radical activity and oxidative stress are still being explored.

But the fact that RF **does do this** has been CLEARLY ESTABLISHED by many research studies.

This increase in free radical levels can and does lead to DNA damage.

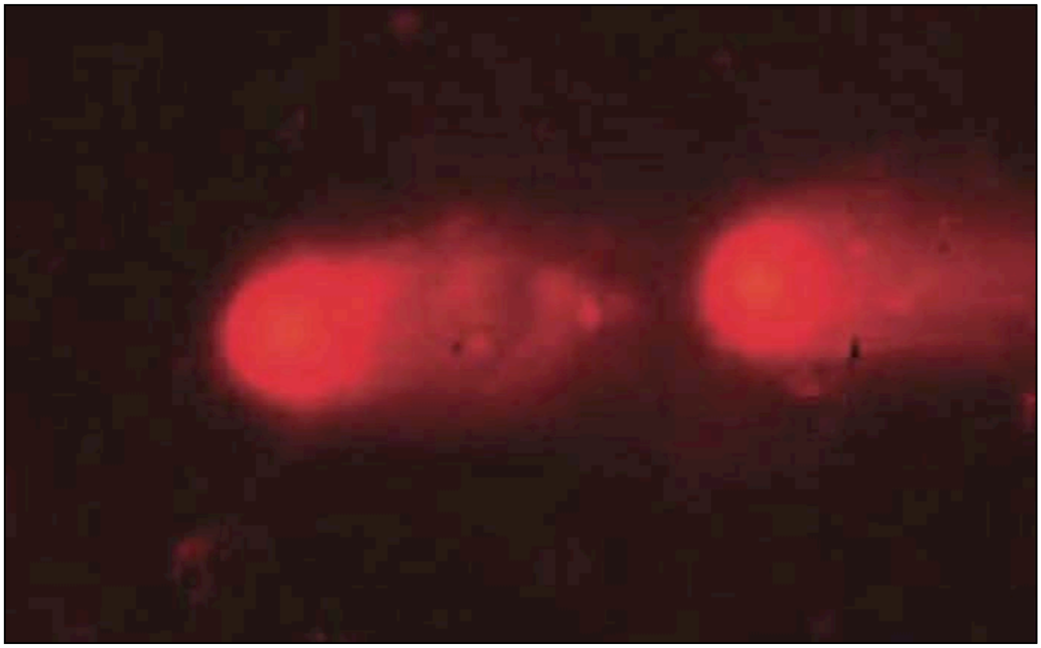
Comet assay: Unexposed control



The Comet assay is one way to measure DNA damage.
This is a study of DNA extracted from normal rat brain cells (unexposed controls).
Electrophoresis: DNA molecules of given mass and charge placed in a diffusion medium.
Preparation placed in a static electric field.
DNA molecules migrate towards a charged pole.
DNA molecules that are the same size, so they migrate at the same rate, will stay in a clump.

Kesari KK, Behari J, Kumar S. Mutagenic response of 2.45 GHz radiation exposure on rat brain. *Int J Radiat Biol* (2010a); 86(4):334-343.

RF exposure: 2.45 GHz @ 0.34 mW/cm2, 2 hours per day x 35 days



DNA from brain cells of exposed rats. Here, some of the DNA molecules are broken.
The broken parts vary in mass and total charge, so they migrate through the gel at different rates
This leaves a "comet tail" of lighter fragments behind the main body of intact DNA.
The length of the tail can be measured.
This is a **very sensitive** assay for DNA damage.

Kesari KK, Behari J, Kumar S. Mutagenic response of 2.45 GHz radiation exposure on rat brain. *Int J Radiat Biol* (2010a); 86(4):334-343.

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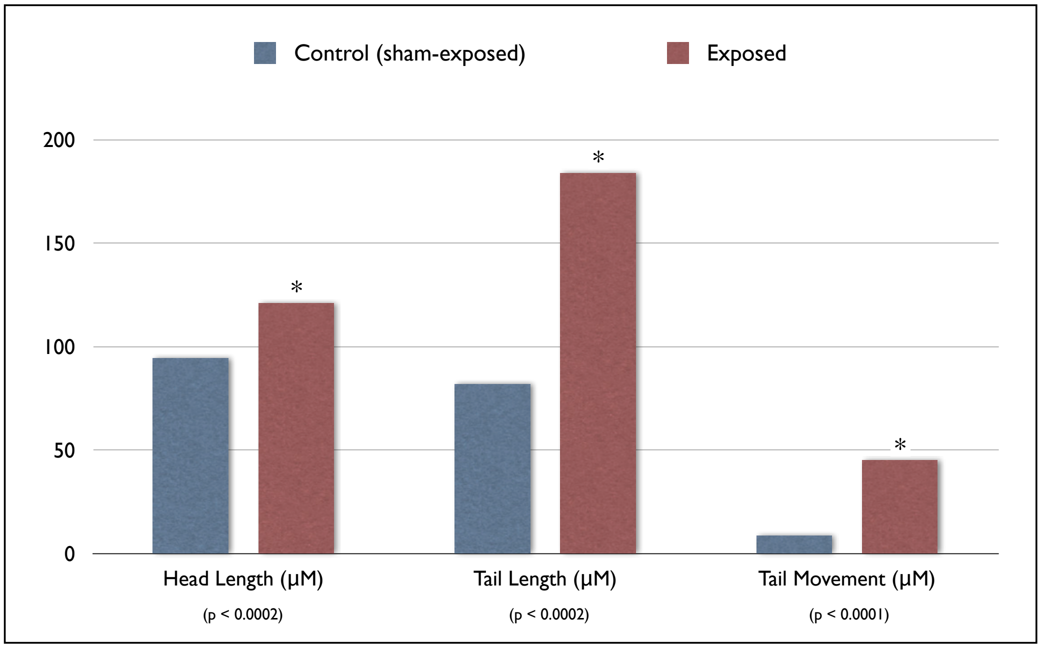


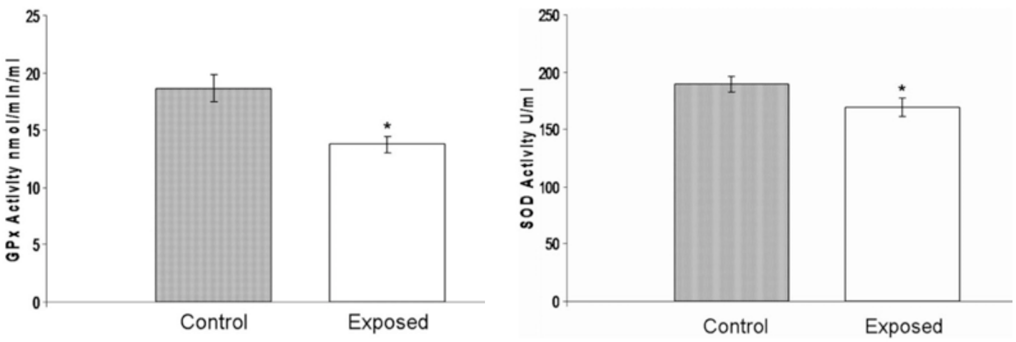
Comet Assay: **Measure of DNA fragmentation** in rat brains, produced by prolonged exposure to microwave RF.

In this study, exposure was 2 h a day for 35 days an exposure level of **one third of the FCC exposure limit.**

FCC exposure limit = 1 mW/cm^2

Kesari KK, Behari J, Kumar S. Mutagenic response of 2.45 GHz radiation exposure on rat brain. *Int J Radiat Biol* (2010a); 86(4):334-343.

RF exposure: 2.45 GHz @ 0.34 mW/cm2, 2 hours per day x 35 days



Depletion of antioxidants in RF-exposed rat brains.

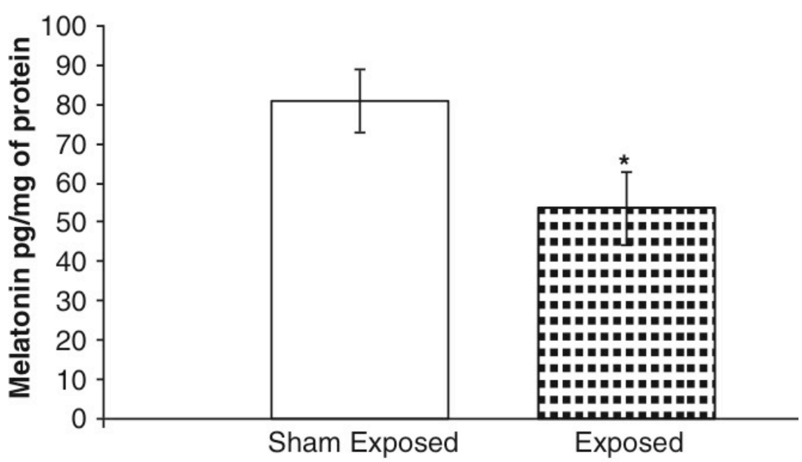
This consumption of anti-oxidants is **evidence of increased oxidant stress**, due to excess free radical production.

Kesari KK, Behari J, Kumar S. Mutagenic response of 2.45 GHz radiation exposure on rat brain. *Int J Radiat Biol* (2010a); 86(4):334-343.

Abstract

Purpose: To investigate the effect of 2.45 GHz microwave radiation on rat brain of male wistar strain. Material and methods: Male rats of wistar strain (35 days old with 130 + 10 g body weight) were selected for this study. Animals were divided into two groups: Sham exposed and experimental. Animals were exposed for 2 h a day for 35 days to 2.45 GHz frequency at 0.34 mW/cm2 power density. The whole body specific absorption rate (SAR) was estimated to be 0.11 W/Kg. Exposure took place in a ventilated Plexiglas cage and kept in anechoic chamber in a far field configuration from the horn antenna. After the completion of exposure period, rats were sacrificed and the whole brain tissue was dissected and used for study of double strand DNA (Deoxyribonucleic acid) breaks by micro gel electrophoresis and the statistical analysis was carried out using comet assay (IV-2 version software). Thereafter, antioxidant enzymes and histone kinase estimation was also performed. Results: A significant increase was observed in comet head (P50.002), tail length (P50.0002) and in tail movement (P 5 0.0001) in exposed brain cells. An analysis of antioxidant enzymes glutathione peroxidase (P 5 0.005), and superoxide dismutase (P50.006) showed a decrease while an increase in catalase (P50.006) was observed. A significant decrease (P 5 0.023) in histone kinase was also recorded in the exposed group as compared to the control (sham-exposed) ones. One- way analysis of variance (ANOVA) method was adopted for statistical analysis. Conclusion: The study concludes that the chronic exposure to these radiations may cause significant damage to brain, which may be an indication of possible tumour promotion (Behari and Paulraj 2007).

RF exposure: 2.45 GHz @ 0.21 mW/cm2, 2 hours per day x 45 days



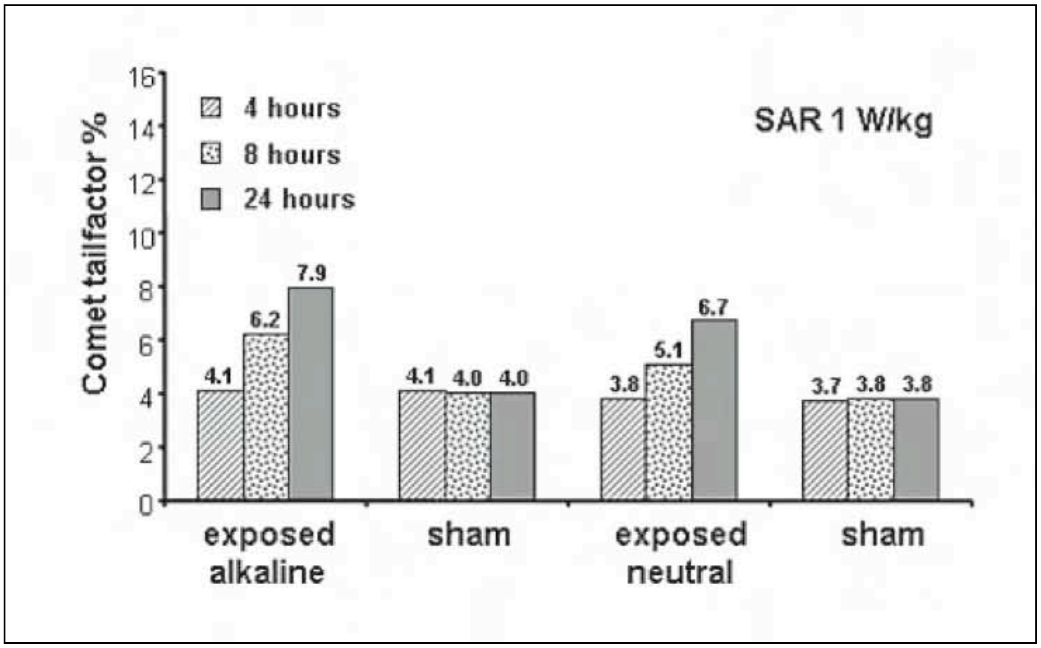
Suppression of melatonin secretion by 2.45 GHz RF:

Bad news, since melatonin is also a potent antioxidant.

Kesari KK, Kumar S, Behari J. Pathophysiology of microwave radiation: effect on rat brain. *Appl Biochem Biotechnol* (2012); 166(2):379-388.

10 MINUTE BREAK HERE

Evidence of DNA damage by microwave RF.



Another study, using Human fibroblasts.

1950 MHz, 5 minutes on/10 minutes off.

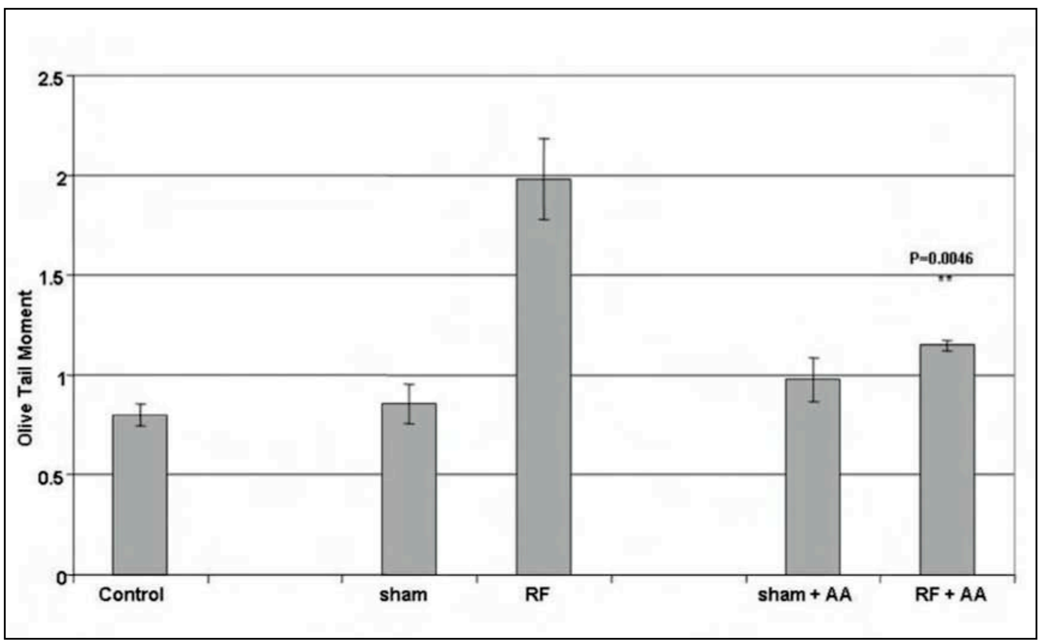
Total exposure for 4, 8, or 24 hours.

DNA fragmentation measured by Comet Assay.

Figure 9. Intermittent RF-EMF exposure (1950 MHz, 5 minutes on/10 minutes off, 1 and 2 W/kg, 4, 8 and 24 hours) increases the DNA strand break frequency in human fibroblasts dependent on the duration of exposure as measured with the alkaline and neutral Comet assay (H.-W. Rüdiger et al., Division of Occupational Medicine, University of Vienna, Austria).

Adlkofer F. Risk Evaluation of Potential Environmental Hazards from Low Energy Electromagnetic Field Exposure Using Sensitive In Vitro Methods. *Bioelectromagnetics* (2006); 331-354.

DNA damage blocked by anti-oxidants



A cell study, with human fibroblasts, exposed to 1950 MHz RF, 5 minutes on/10 minutes off.

(right hand columns => **DNA damage blocked by anti-oxidant** effect of vitamin C (ascorbic acid).

The research group of Prof. Tauber, Berlin, investigated the effect of RF- EMF on HL-60 cells, i.e. a human promyelocytic cell line. After continuous exposure to RF-EMF of 1800 MHz and a SAR value of 1.3 W/kg they observed a highly significant increase in the number of single and double DNA strand breaks as measured by the alkaline Comet assay and of micronuclei as measured with the micronucleus test, thus fully confirming the findings obtained in the Vienna laboratory. Additionally, as clearly shown in Figures 12 and 13, the generation of DNA strand breaks and micronuclei can be prevented, when the radical scavenger ascorbic acid is added to the culture medium before exposure.

Figure 12, from: Adlkofer F. Risk Evaluation of Potential Environmental Hazards from Low Energy Electromagnetic Field Exposure Using Sensitive In Vitro Methods. *Bioelectromagnetics* (2006); 331-354.