

**Man-made Electromagnetic Fields (EMFs),  
Voltage-Gated Ion Channel (VGIC) dysfunction in cell membranes,  
Oxidative Stress (OS),  
DNA damage and related pathologies**

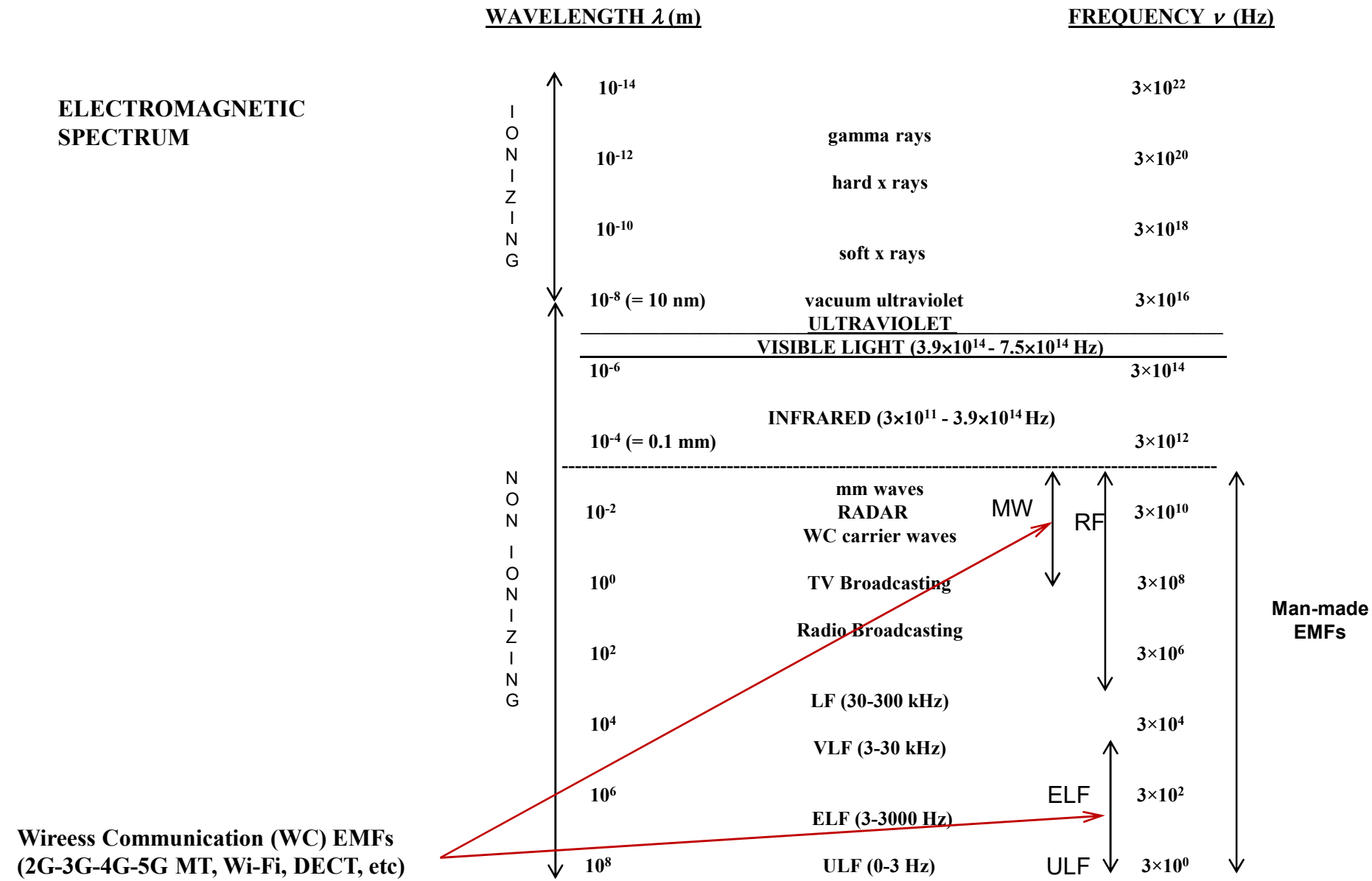
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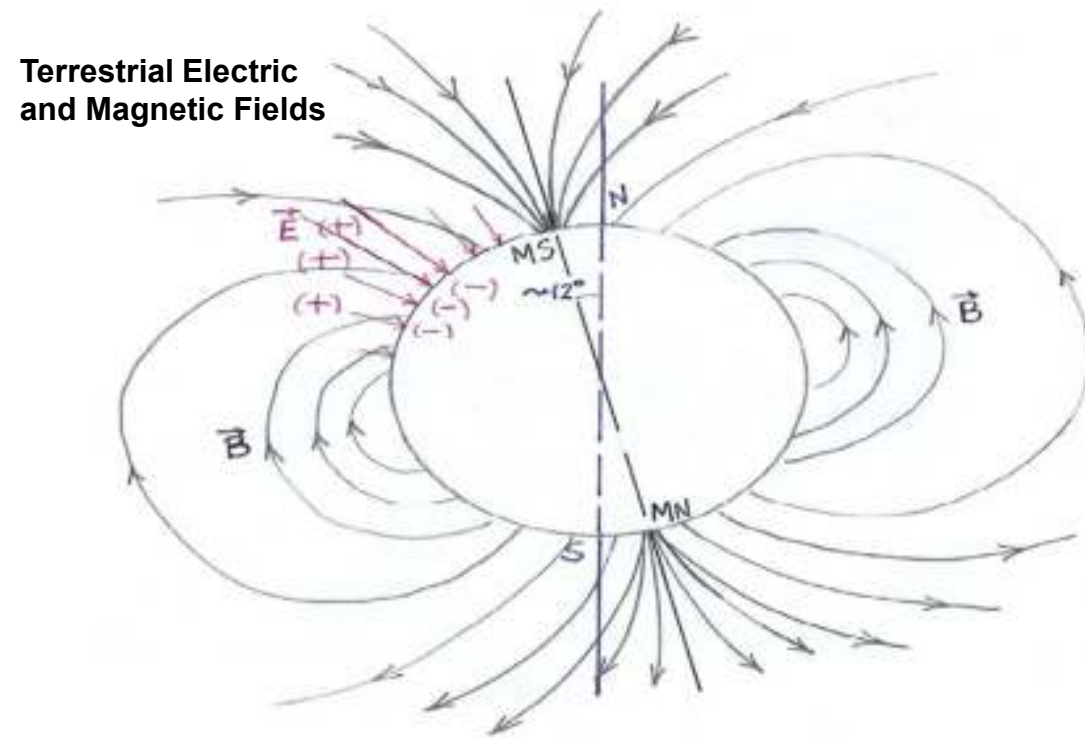
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**ELECTROMAGNETIC SPECTRUM**

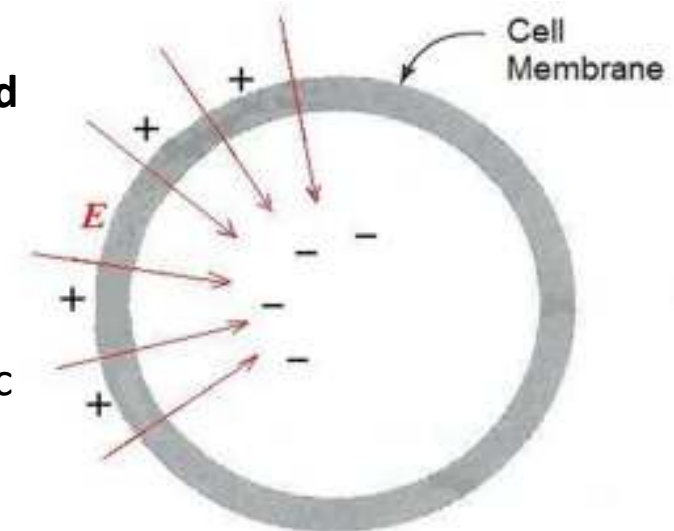


## Natural Environment is Electromagnetic (EM) Life is Electromagnetic

**All living Organisms have EM Nature** (endogenous E-fields in cells/tissues, nerve impulses, brain and heart oscillations, etc.), **and live within a Natural EM Environment** (terrestrial and atmospheric EMFs)

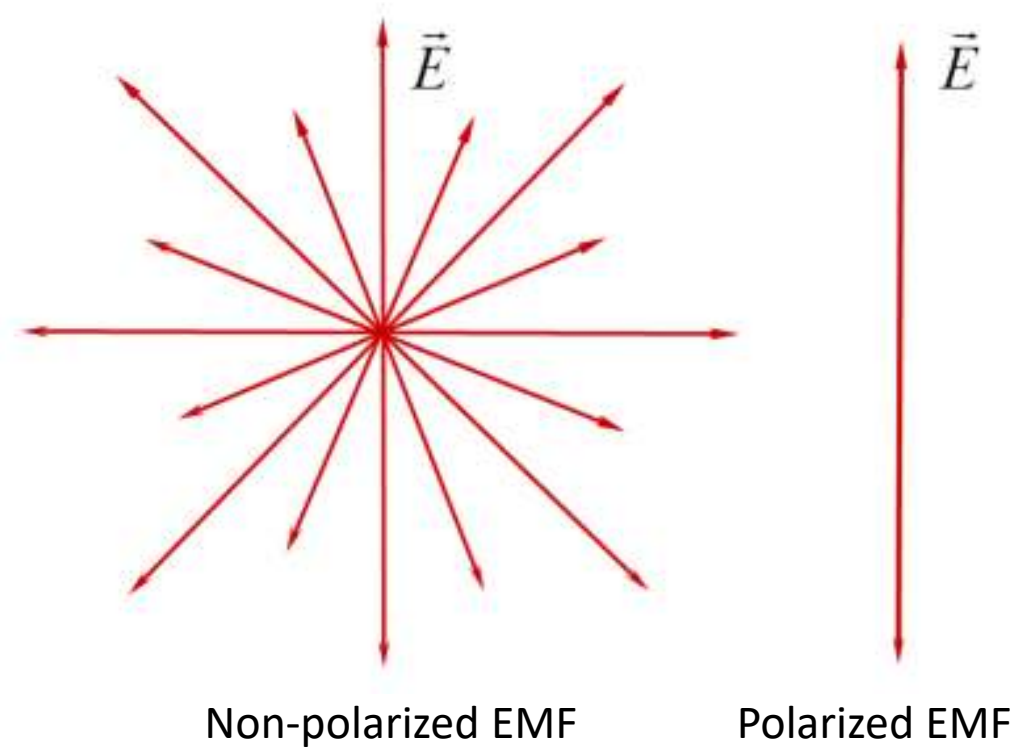


**Both terrestrial and cell membrane fields are static and locally polarized,** in contrast to the majority of natural EMFs which are oscillating and non-polarized (Schumann oscillations, cosmic microwaves, light, gamma radiation, etc.). **Intensity variations by 20-30% in these fields initiate biological/health effects**



Endogenous EMFs in living organisms are in constant interaction with External Natural EMFs [brain oscillations are triggered by the atmospheric (Schumann) oscillations]

Inevitably, Man-Made EMFs interact with Endogenous EMFs in all organisms, and they may distort the biological functions controlled by them



**All Man-made EMFs are totally Polarized and Coherent**

**Natural EMFs are never totally polarized**

**Terrestrial and Cell Membrane E-fields are locally polarized and static**

**Unique properties of polarized and coherent (man-made) EMFs**

1. They can produce constructive interference and amplify their intensities at certain locations
2. They force all charged particles (e.g. mobile ions) in living cells/tissue to oscillate in parallel and in phase with them

**Polarization and Coherence is The reason why EMR  $\sim 0.1 \text{ mW/cm}^2$  from a mobile phone is damaging, while solar EMR  $\sim 10 \text{ mW/cm}^2$  (100 times stronger) is vital.**

[Panagopoulos et al, (2015a): Polarization: A Key Difference between Man-Made and Natural EMFs, in regard to Biological Activity, *Nature, Scientific Reports*, 5, 14914]

Important Observation:

**Intensity variations of the order of 20-30% in natural static and polarized/coherent EMFs (terrestrial electric and magnetic fields, cell membrane electric fields) induce cellular/health effects.**

Important Suggestion:

**Biological/Health Effects initiate when Polarized and Coherent EMFs undergo variations of  $\geq 20-30\%$  of their normal intensities**

Now, All Man-made EMFs are totally polarized and coherent, and  
All Wireless Communication (WC) EMFs are highly variable with unexpected changes exceeding by more than 100% their normal average intensities.

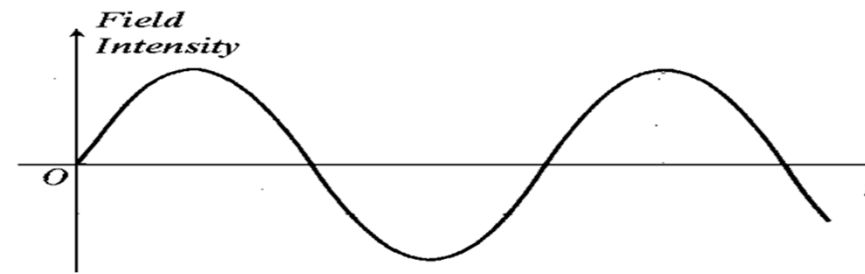
**The vast majority of biological/health effects of all man-made EMFs at environmental intensities are NON-THERMAL (they are not accompanied by any significant tissue temperature increases)**

[Panagopoulos DJ, (2019): Comparing DNA Damage Induced by Mobile Telephony and Other Types of Man-Made Electromagnetic Fields. *Mutation Research Reviews*, 781, 53-62.]

## Main Sources of EMF pollution



### 1. High –Voltage Power Line EMFs (50-60 Hz: ELF)



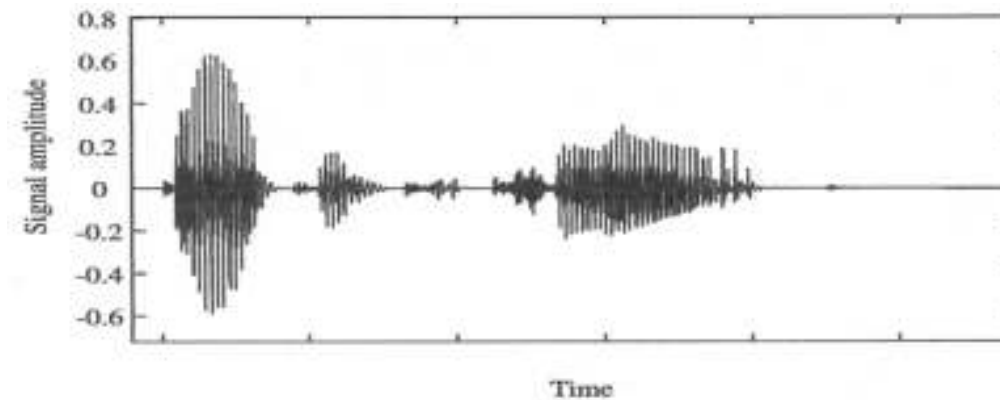
Continuous-wave  
ELF EMFs

**Increased Cancer Risk** is found in epidemiological studies for **Distances up to 600 m** ( $E= 10 \text{ V/m}$ ,  $B=2 \text{ mG}$ )



### 2. WC EMFs (2G-3G-4G-5G MT, Wi-Fi, DECT, etc)

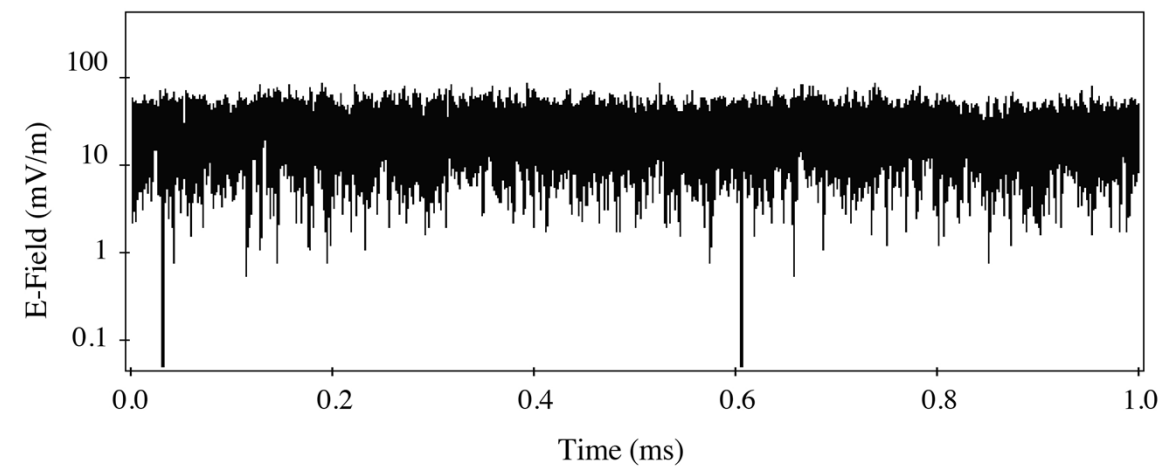
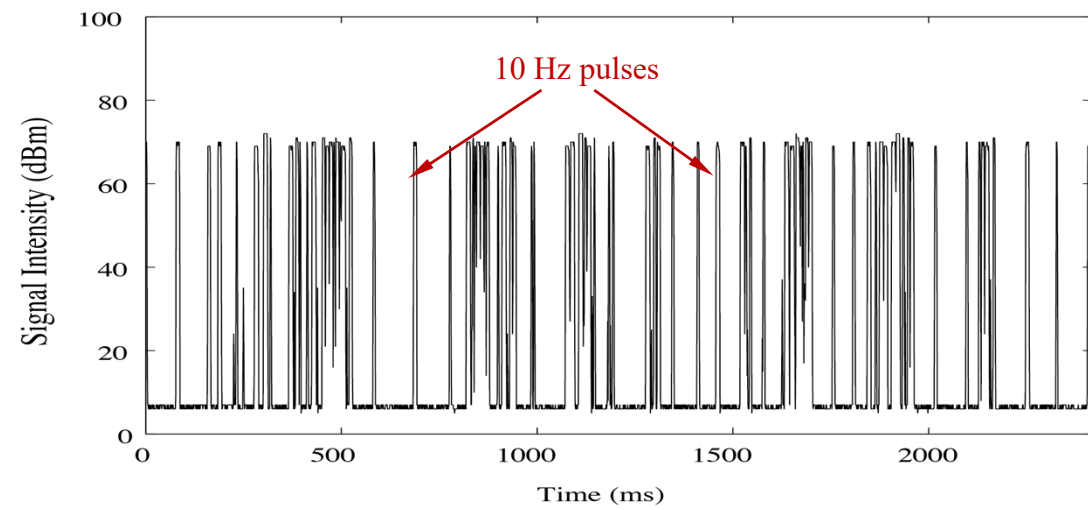
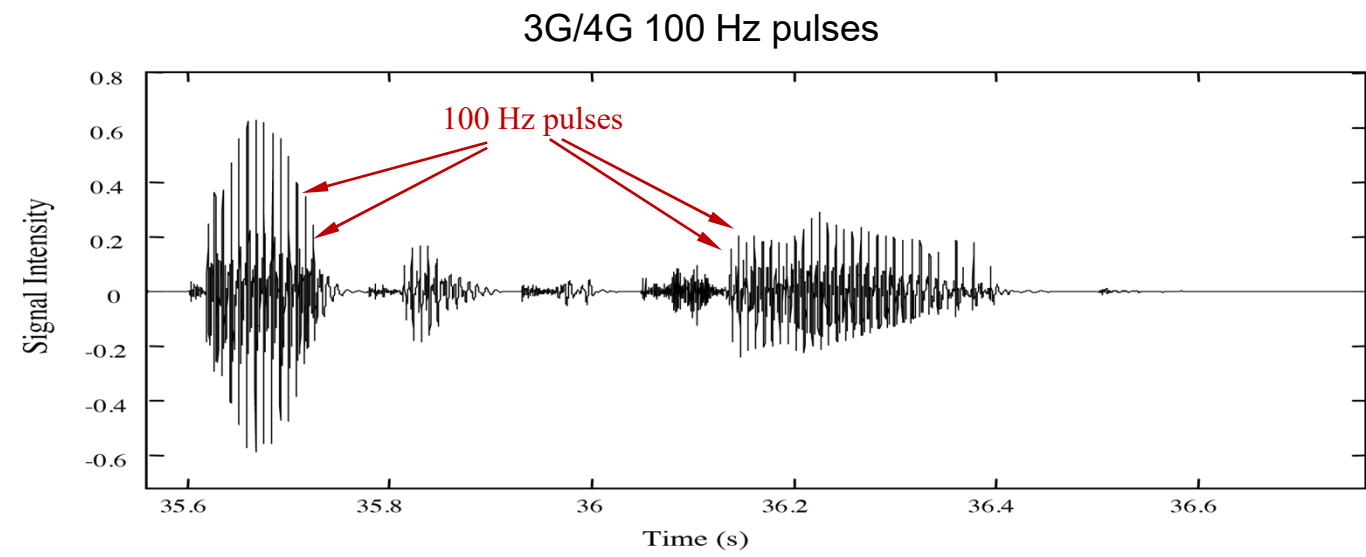
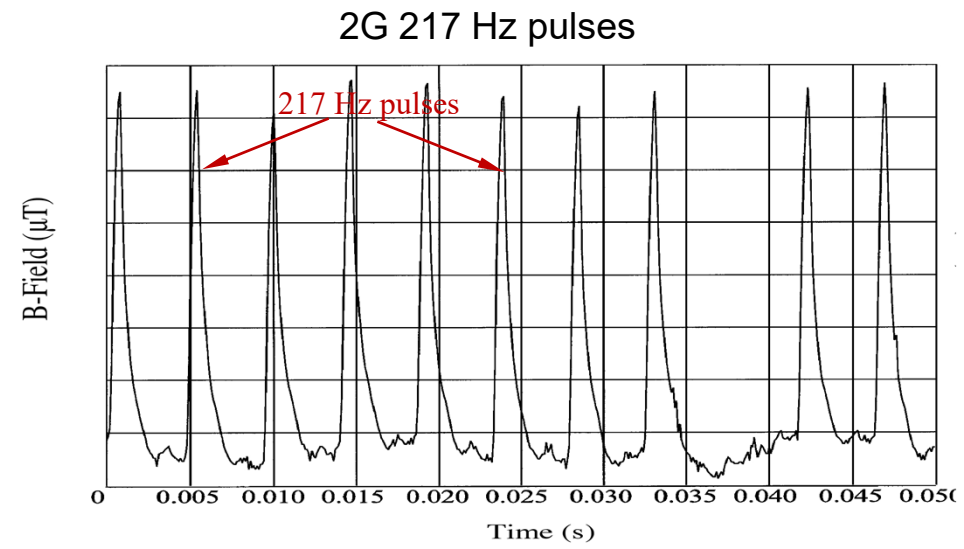
They all combine RF/microwave carrier frequencies with ELF/ULF (0-3000 Hz) EMFs in the form of pulsing, modulation, and random variability



Pulsing RF EMFs with  
ELF/ULF pulsation,  
modulation, variability

**The non-thermal biological effects of WC EMFs are due to the included ELF/ULF EMFs**  
(Panagopoulos 2022)

## ELF/ULF Pulsation and Variability of WC signals

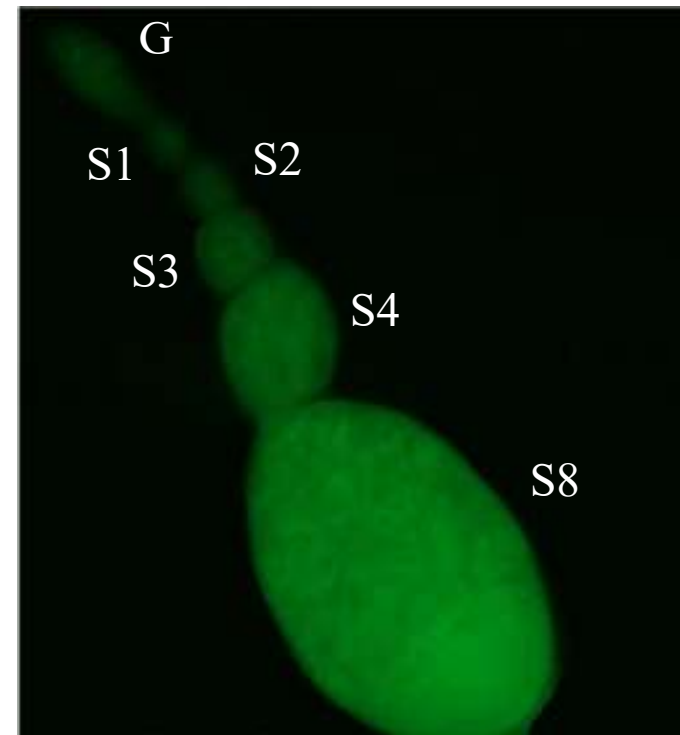


Wi-Fi 10 Hz pulses

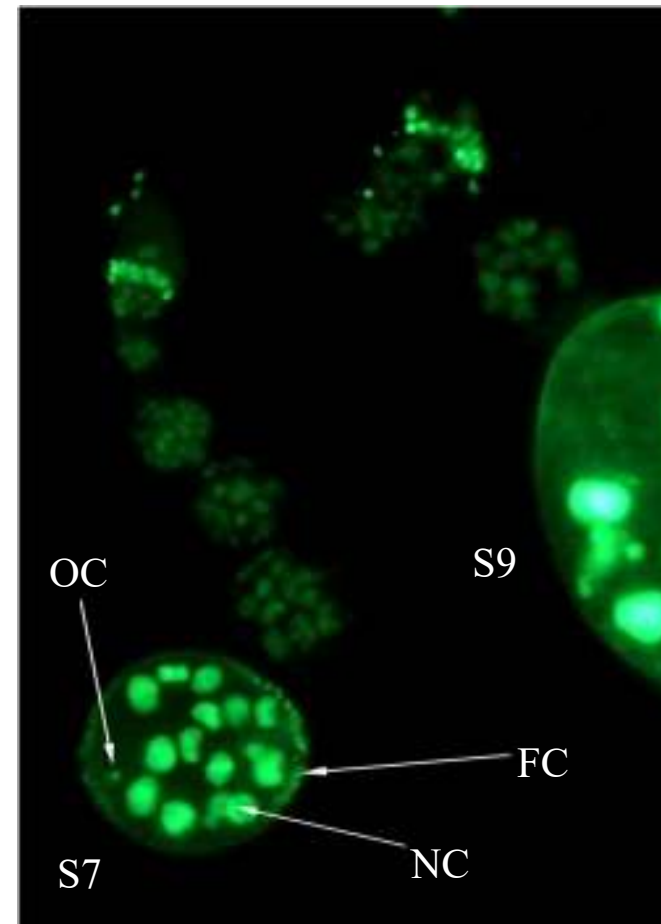
Variability of a WC signal

## DNA Fragmentation in fruit fly ovarian cells after Exposure to WC EMFs

**TUNEL-negative**  
**fluorescent picture of an**  
**ovariole** of a Sham-  
Exposed female insect,  
containing egg chambers  
from germarium (G) to  
stage 8 (S8).



**DNA fragmentation in**  
**all developmental**  
**stages** during early-  
and mid-oogenesis,  
**and in all three types**  
**of egg chamber cells:**  
NC, FC, OC



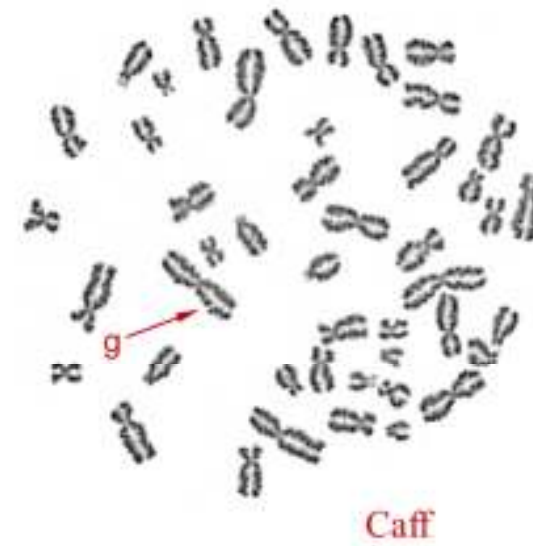
Panagopoulos DJ, Chavdoula ED, Nezis IP and Margaritis LH, (2007): Cell Death induced by GSM 900MHz and DCS 1800MHz Mobile Telephony Radiation, *Mutation Research*, 626, 69-78. ▼

Panagopoulos DJ, Chavdoula ED and Margaritis LH, (2010): Bioeffects of Mobile Telephony Radiation in relation to its Intensity or Distance from the Antenna, *International Journal of Radiation Biology*, 86(5), 345-357.



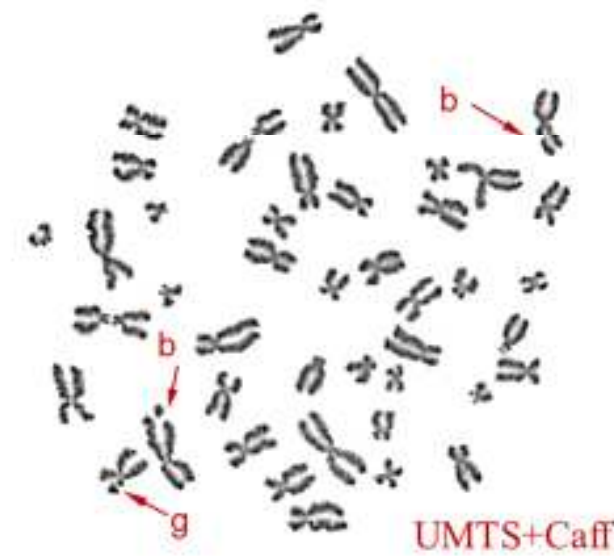
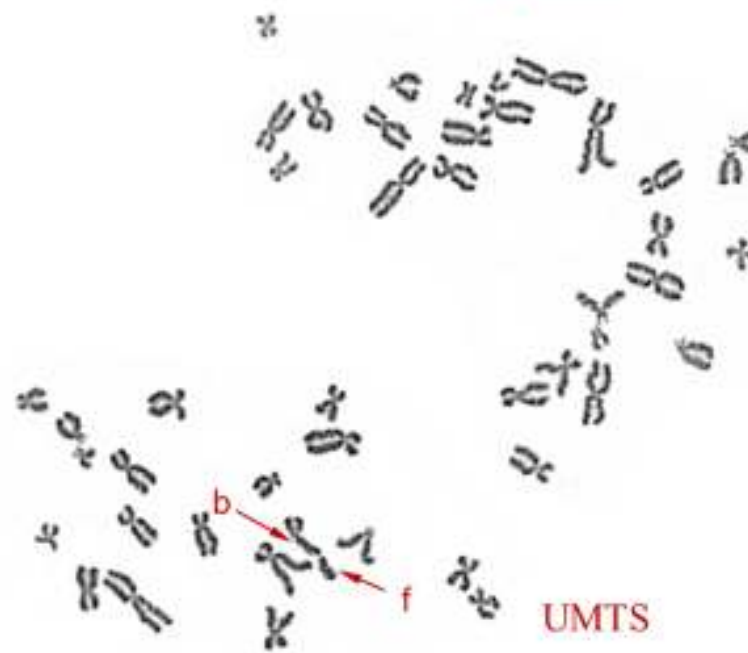
**Chromatid gaps (g) and breaks (b) in human cells after Exposure to WC EMFs and/or an extreme Caffeine dose**

Unexposed human peripheral blood lymphocyte (HPBL)



HPBL exposed to Caffeine dose ~ 290 times greater than the permitted dose for an adult human

HPBL exposed to UMTS (3G/4G) EMF ~ 136 times below the latest ICNIRP (2020) limit



HPBL exposed to the combination of UMTS (3G/4G) EMF and Caffeine

Experimental Result:  
**Real-life WC EMFs are significantly more damaging than other types of man-made EMFs** (Panagopoulos 2019)

**~ 65-70 % of all peer review published studies with WC EMFs find effects**

**Among studies with Simulated Exposures  
(as suggested by health authorities):  
~ 50% find effects**

**Among studies with Real-life Exposures:  
more than 95% find effects**

Important Observation:  
**Except for Polarization/Coherence, Intensity, ELF, Duration of exposure,  
the Variability of WC EMFs is an important Bioactive Factor**

Panagopoulos DJ, Johansson O, Carlo GL, (2015b): Real versus Simulated Mobile Phone Exposures in Experimental Studies, *BioMed Research International*, 2015:607053.  
Panagopoulos DJ, (2019): Comparing DNA Damage Induced by Mobile Telephony and Other Types of Man-Made Electromagnetic Fields. *Mutation Research Reviews*, 781, 53-62.

## Existing Exposure Guidelines based on ICNIRP recommendations provide No Protection

Threshold EMF/EMR intensities for indicative biological/health effects and corresponding ICNIRP (2020) limits

Incident EMF	ICNIRP Intensity limit (6 min average, local exposure)	Threshold Intensity for effect initiation	Exposure Duration	Effect	Reference
ELF-E (CW or pulsed) (1-50 Hz)	5000 V/m	0.002 V/m	12 h	Decrease in protein synthesis rate	McLeod et al (1987)
		0.0021 V/m	4 days	Increase in DNA synthesis rate	Cleary et al (1988)
		10 V/m	years	Cancer (humans)	Coghill et al (1996)
ELF-B (50 Hz CW)	2 G (200 $\mu$ T)	0.002 G (0.2 $\mu$ T)	years	Cancer (humans)	Feychting and Ahlbom (1994)
Pulsed RF (GSM) 1800 MHz	3655.6 $\mu$ W/cm <sup>2</sup>	< 1 $\mu$ W/cm <sup>2</sup>	6 min/day, 6 days	DNA damage, cell death (fruit fly ovarian cells)	Panagopoulos et al (2010)
Pulsed RF (GSM) 900 MHz	2014.0 $\mu$ W/cm <sup>2</sup>	0.25 $\mu$ W/cm <sup>2</sup>	158–360 h intermittently	OS, DNA damage, embryonic death (bird embryos)	Burlaka et al (2013)
Pulsed RF (GSM) 1800 MHz	3655.6 $\mu$ W/cm <sup>2</sup>	0.32 $\mu$ W/cm <sup>2</sup>	19 days (48s On/12s Off)	OS, DNA damage, embryonic death (bird embryos)	Yakymenko et al (2018)

## **Explanation of the Genotoxic Action of the Polarized and Coherent (man-made) Oscillating EMFs**

**Genetic Damage** due to man-made EMF Exposure is found to coexist with **Oxidative Stress (OS)** and it is apparently due to OS (Yakymenko et al 2016; Yakymenko and Tsybulin 2022)

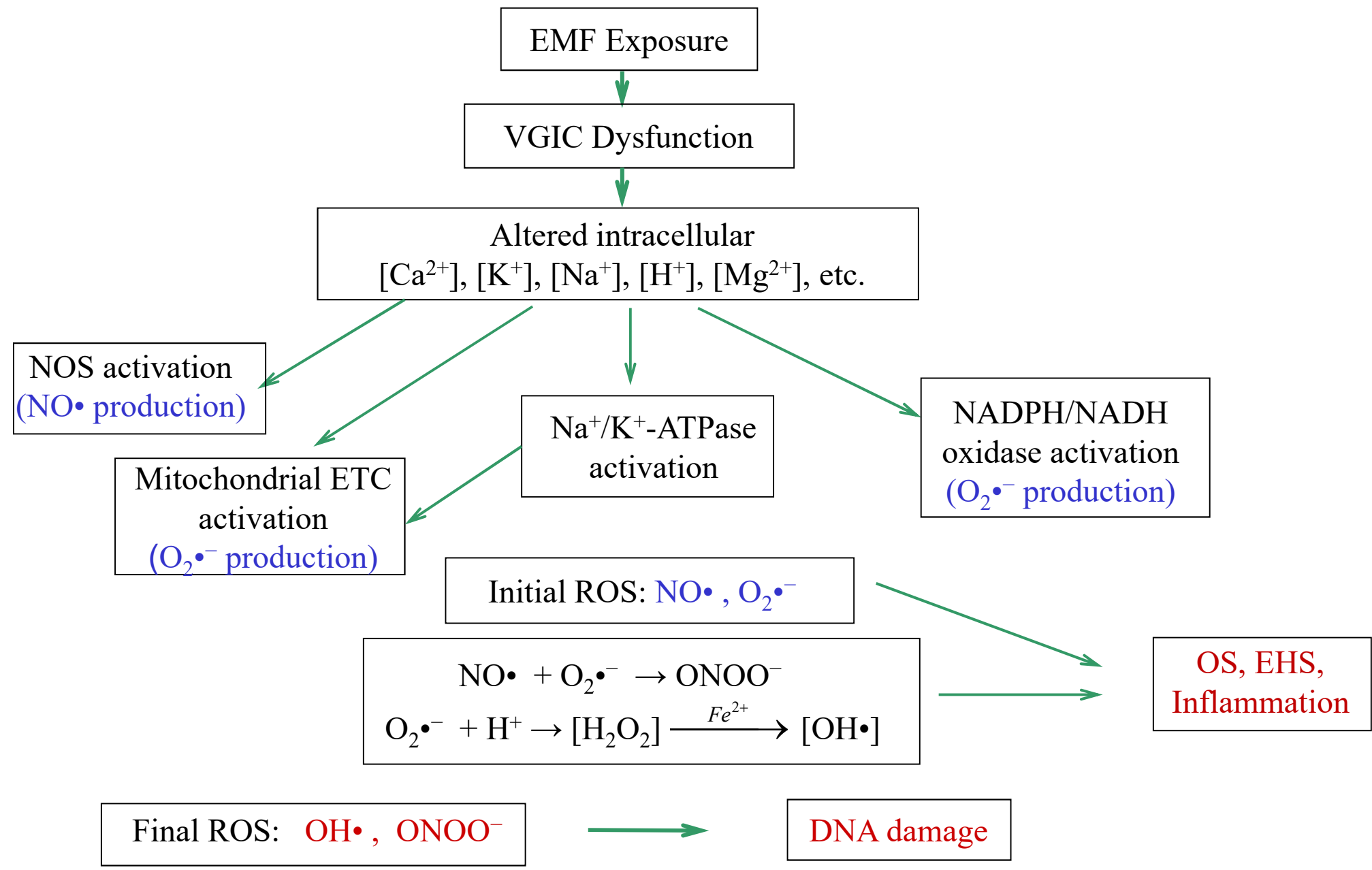
Polarized/Coherent and Oscillating/Varying EMFs cause **irregular opening and closing of Voltage-Gated Ion Channels (VGICs)** in cell membranes (Panagopoulos et al 2000; 2002; 2015; 2021)

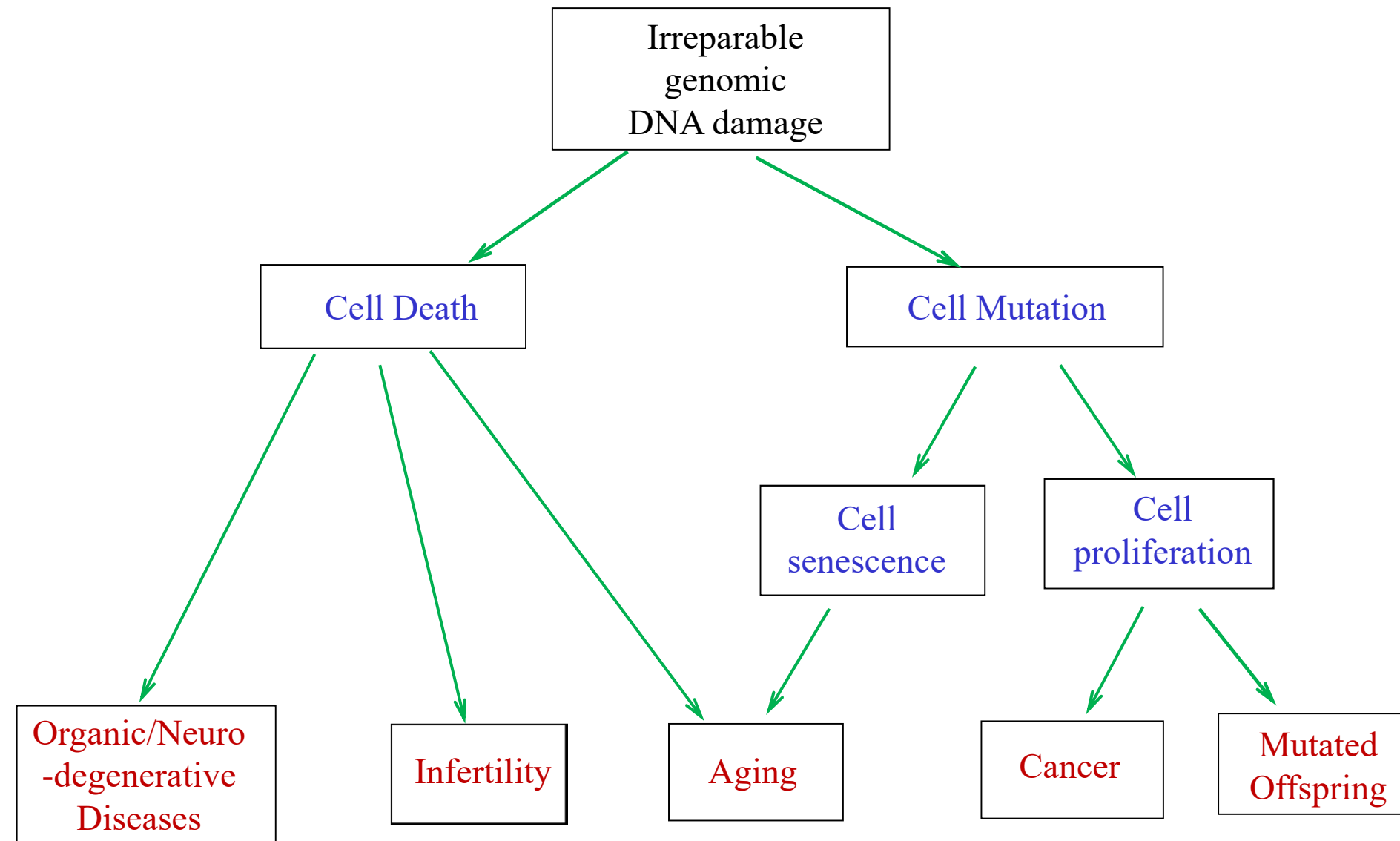
The induced **VGIC dysfunction alters the normal ion concentrations** within the cell. This disrupts the cell's electrochemical balance and homeostasis, and the redox status of the cell.

This causes **(over)production of Reactive Oxygen Species (ROS) and creates OS** within the cell. Initial ROS are the superoxide anion free radical ( $O_2^{\bullet-}$ ), and the nitric oxide free radical ( $NO^{\bullet}$ ) (Panagopoulos et al 2021)

EHS is also connected with chronic OS and tissue inflammation (De Luca et al 2014; Irigaray et al 2018; Belpomme and Irigaray 2020)

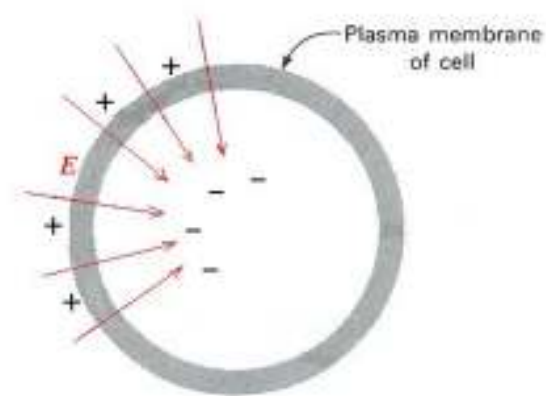
The initial ROS can be converted into the most powerful ROS hydroxyl free radical ( $OH^{\bullet}$ ), and peroxynitrite ( $ONOO^-$ ) which are finally those that damage DNA and other critical biomolecules



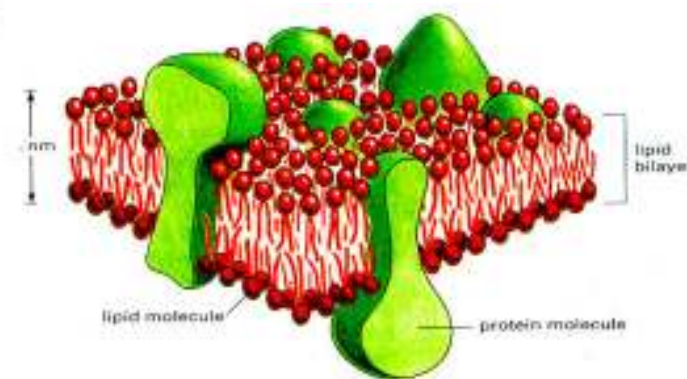


## Cell Membranes and Voltage-Gated Ion Channels (VGICs)

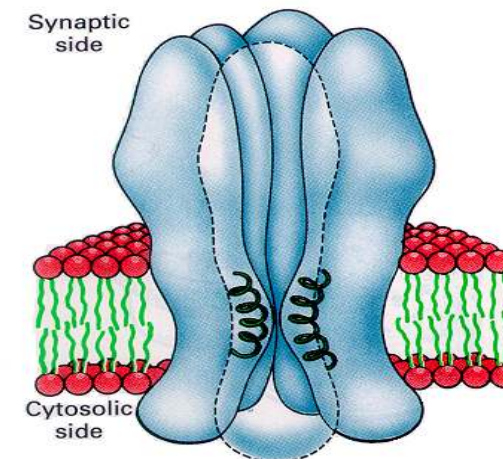
Across all cell membranes there is a strong Electric field, mainly determined by free ion concentration differences between the two sides of the membrane



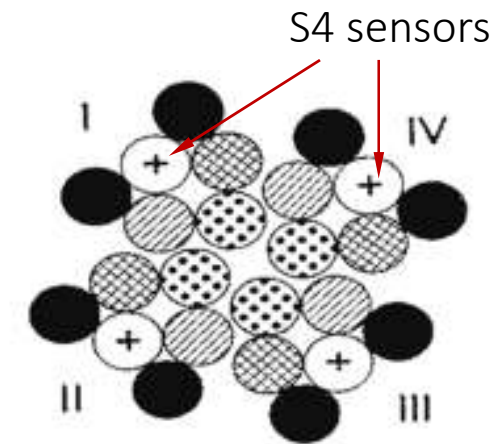
Cell Plasma Membrane and its electric field



Cell Membrane structure



Ion Channel structure



VGIC cross-section and the positively charged S4 helices (voltage-sensors)

Most Cation Channels in cell membranes are “**Electro-sensitive**” or “**Voltage-Gated**” (VGICs).

They open or close by electric forces on their voltage-sensors exerted by changes in the transmembrane voltage  $\partial V \geq 30 \text{ mV}$ .

The voltage sensors are four symmetrically arranged, transmembrane, positively charged  $\alpha$ -helices, each one called **S4**

## “Ion Forced-Oscillation and VGIC Dysfunction (IFO-VGIC) mechanism”

(Panagopoulos et al 2000; 2002; 2015a; 2021)

### Theory's Main Points

- **Forces** exerted by the external field **on the mobile ions** around cell membranes and within VGICs
- **Mobile Ions are Forced to Oscillate** in parallel and in phase with the oscillating polarized EMF
- Oscillating Ions exert **Constructive Forces on the S4 sensors of the VGICs**
- These forces are **similar to those exerted by changes  $\geq 30$  mV in the membrane voltage** that physiologically open/close VGICs
- This causes **Irregular opening/closing (dysfunction) of VGICs**
- This causes **Disruption of cell's electrochemical balance and ROS overproduction** in the cell



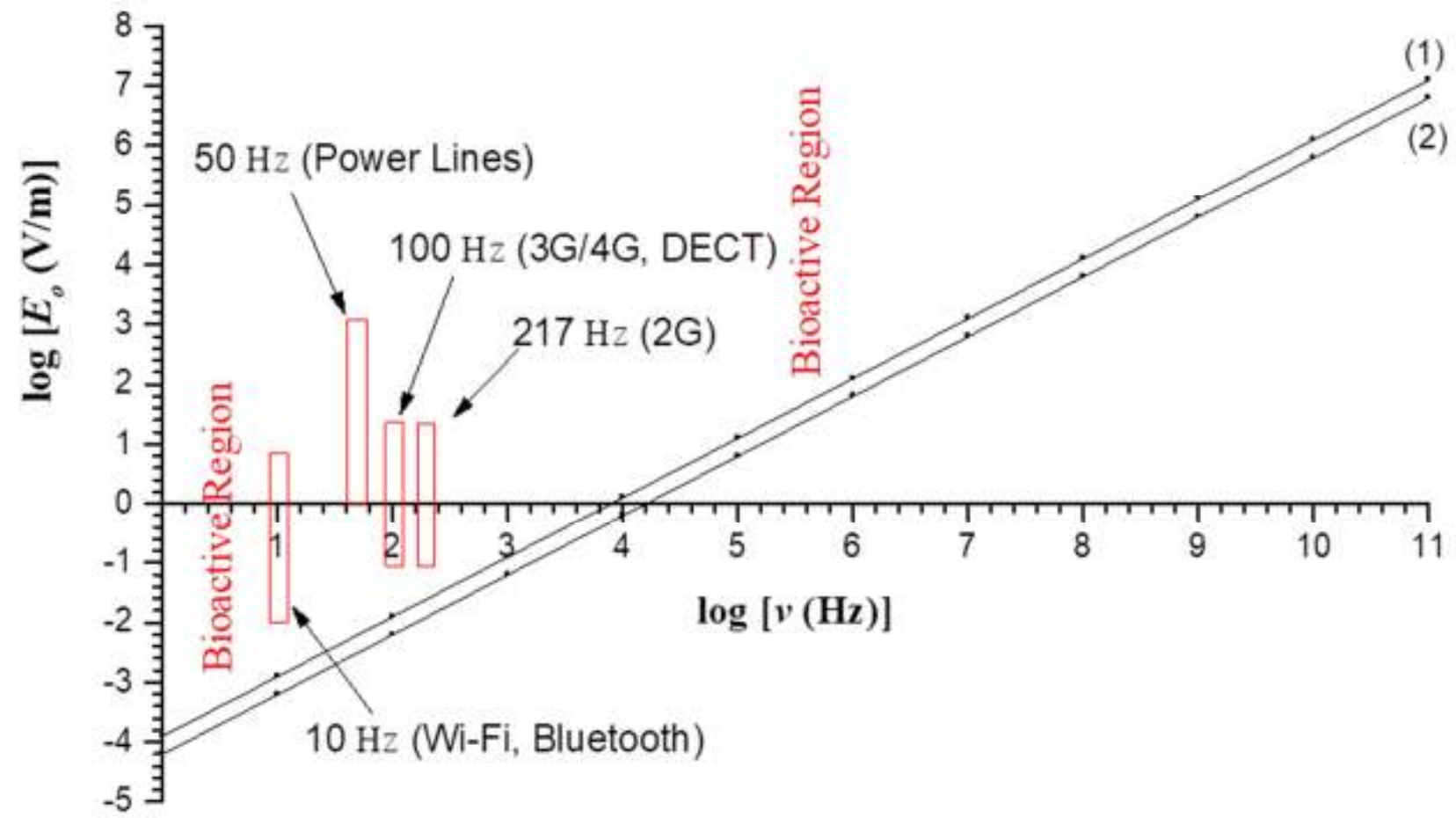
### Theory's Predictions

The Bioactivity of Polarized/Coherent and Oscillating EMFs is proportional to the Intensity ( $E$ ), inversely proportional to the Frequency ( $\nu$ ), and doubles/multiplies for pulsed/varying EMFs

$$EMF \text{ Bioactivity} = \frac{E_o z q_e}{\beta \omega} = k \cdot \frac{E_o}{\nu}$$

- 1. The Higher the Intensity the more bioactive the EMF**
- 2. The Lower the Frequency the more bioactive the EMF** [This explains the experimental data indicating that ELF EMFs are the most bioactive, and that the biological action of RF/Microwave fields is due to their ELFs (pulsing, modulation)]
- 3. Pulsing and Variability multiply the bioactivity.** [This explains the higher bioactivity of pulsed and/or modulated EMFs compared to continuous and/or non-modulated corresponding EMFs reported in many experiments]
- 4. The Electric and not the Magnetic part of an EMF is the most bioactive factor** [in contrast to what was considered by health agencies and most experts]

### E-Field Bioactivity Diagram



## **Protective Suggestions**

**Avoid any unnecessary exposure to man-made EMFs.**

**Avoid living close to any antennas or high-voltage power lines**

**Mobile Phones:** 1) Make use of the loudspeaker or air-tube headsets and keep the handset  $\geq 40\text{-}50$  cm from the body, 2) Minimize number and duration of calls, 3) Do not carry the device in your hands or on your body while it is On. Set it to airplane mode, 4) Keep it at the greatest possible distance (several meters) at home/work, 5) Turn it off during sleep.

**Use Wire Connections for Domestic Phones and Internet**

**Disable Wi-Fi and Bluetooth from Cars and Devices (mobile phones, printers, etc.)**

**Educate parents and pregnant women not to expose embryos and kids (possible correlation with autism and autoimmune diseases need to be carefully investigated)**

**Avoid permanent and complete Shielding** as this may cause internal desynchronization (Wever 1979; Panagopoulos and Chroussos 2019)

**Urgent Need for drastic Reconsideration of current Exposure Limits especially for ELF, RF/microwaves and activation of Precautionary Principle and ALARA**