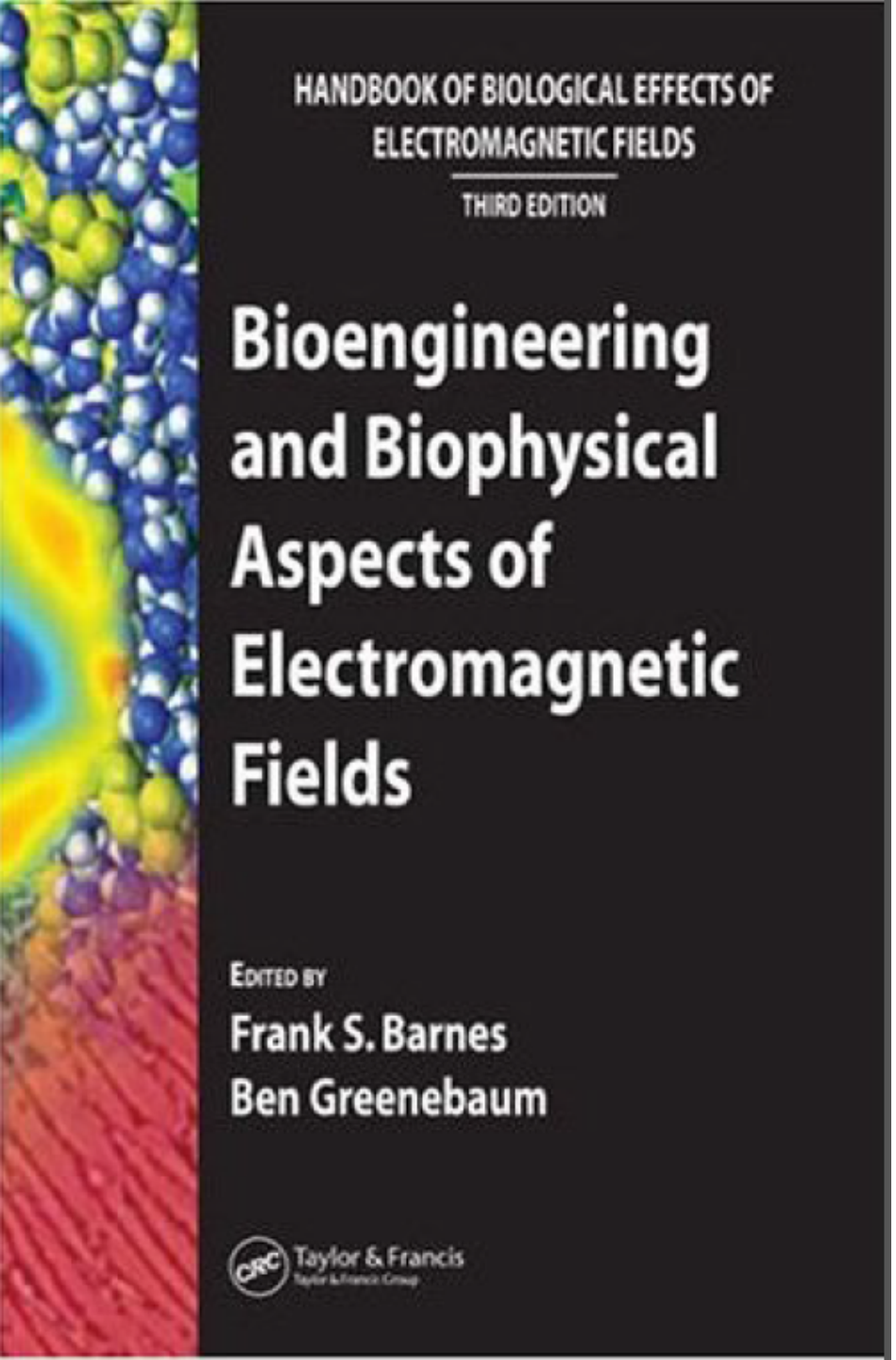

Weak Magnetic and RF Fields

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Objective of this Talk

1. To provide a brief description of some theory and experiments that provide a basis for the mechanism for going from the physics through the chemistry to biological changes that can lead to health effects.
2. Understanding how weak *magnetic and radio frequency* electromagnetic fields can change concentrations of radicals, reactive oxygen and nitrogen which in turn can cause health effects.
3. Outline a model for feedback and repair processes to help explain why we can see positive, negative and no change in things like cancer growth rates.
4. Some speculation on possible implications of long term low level exposures to weak RF fields.

Background

1. The debate about possible health effects radio frequency and “Are there health effects for exposure levels below those that lead to significant heating?” Meaning typically a temperature rise of 1° C. has been going on for at least 50 years

2. A philosophical approach to setting standard that is to let the technology develop useful applications by setting the standards below the lowest level proven to be dangerous plus a safety factor.

3. If we were to require that a new technology be safe against things we have not thought of we would not introduce it.

Limited Summary of Current Standards

1. At low frequencies the limits are set on the basis of electric fields large enough to *fire a nerve cell*.
   E ≈ 5kV/m for f< 368Hz

2. At RF exposure limits are set on the ***basis of heating*** or a specific absorption rate (SAR),
   SAR = 1.6W/kg over 1gram at 900MHz

3. Far Field exposures of
   P= 1mW/cm^2 for 6 minutes, 30MHz to 300MHz frequency range

Limited Summary of Current Standards

- The current standards do not address the possibility of biological or possible health effects from long term low level exposures of electric and magnetic fields.

- This is for good reasons, including the difficulty in getting reproducible results, lack of a mechanism for going from the **physics through the chemistry to biological changes** that can lead to health effects.

Background Experiments

1. **Decreases in cell growth in fibrosarcoma HT1080 and pancreatic AsPC-1cells for magnetic fields less than 18 µT.**
   (Martino, et al. Bioelectromagnetics pp:1 to 7 (2010)

2. **Decreases in cancer incidence in mice and rats**
   (Boorman, et al., Toxicol. Pathol., 27, 267–278, 1999)

3. **Increase in cell growth rates with RF and a *50% increase* in the H_2O_2 concentrations**

   (Usselman et al. PLOS ONE 2014)

Background Experiments(continued)

4. Measured changes in free radical concentrations

(M. Lantow et.al. Radiat Environ Biophys (2006)DOI 10.1007/s00411-006-0038-3)

(Martino, et al. Bioelectromagnetics pp:1 to 7 (2010)

5. The Interphone Study.

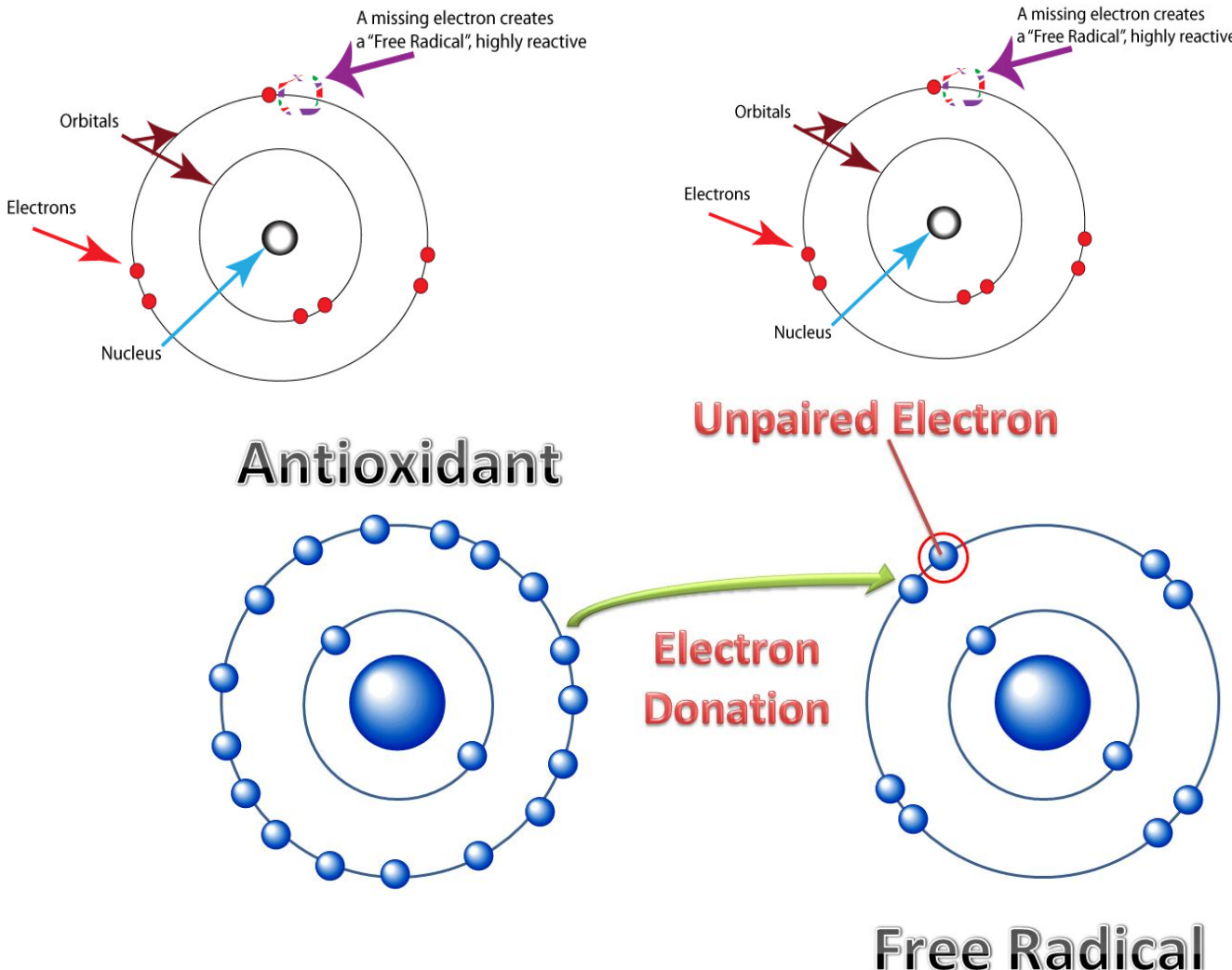
(International Journal of Epidemiology 2010;39:675–694)

Hypothesis

1. **We can change concentrations of free radicals O_2^-, OH^-, NO and H_2O_2 and Ca^{2+}which are not radicals with magnetic fields.**
2. **These molecules are both molecules that are used in signaling biological systems and they can do damage to *proteins, lipids and* ***DNA*****.**
3. **There are feedback and repair processes so we do not see damage most of the time.**

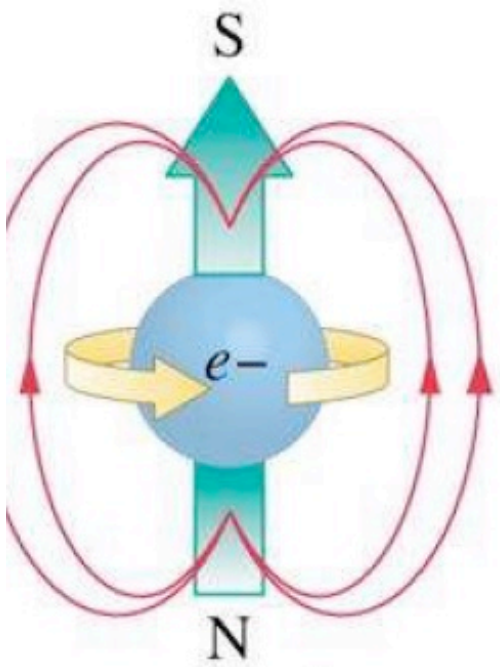
Free Radicals

1

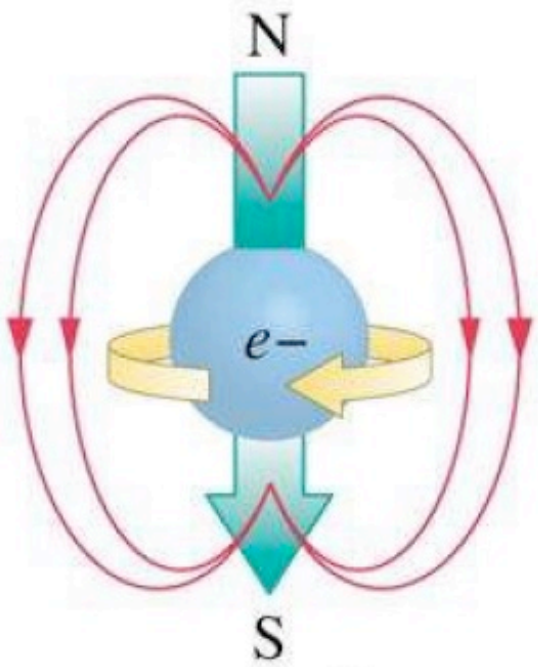


Magnetic Fields Couple to the Magnetic Moment of the Electrons and Can Change the Energy and the Angular Momentum

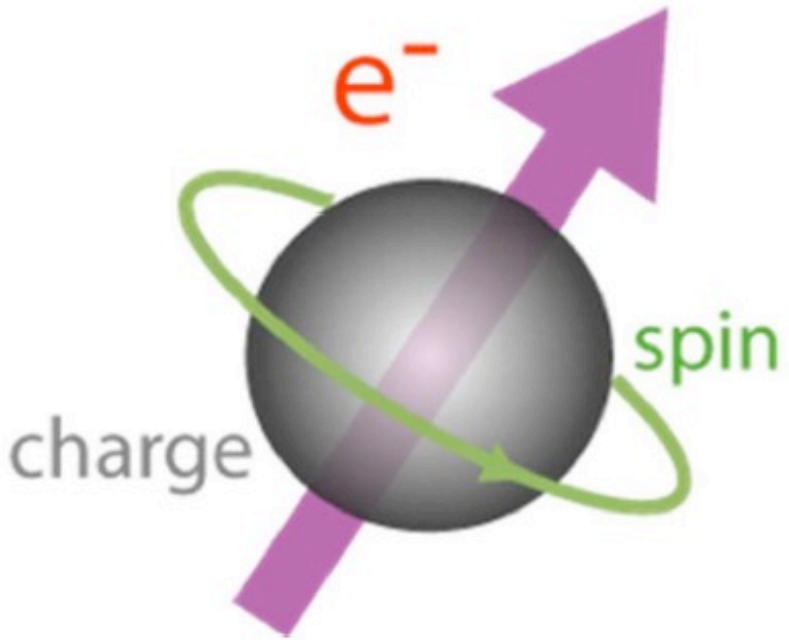
e^- Angular momentum from Spin



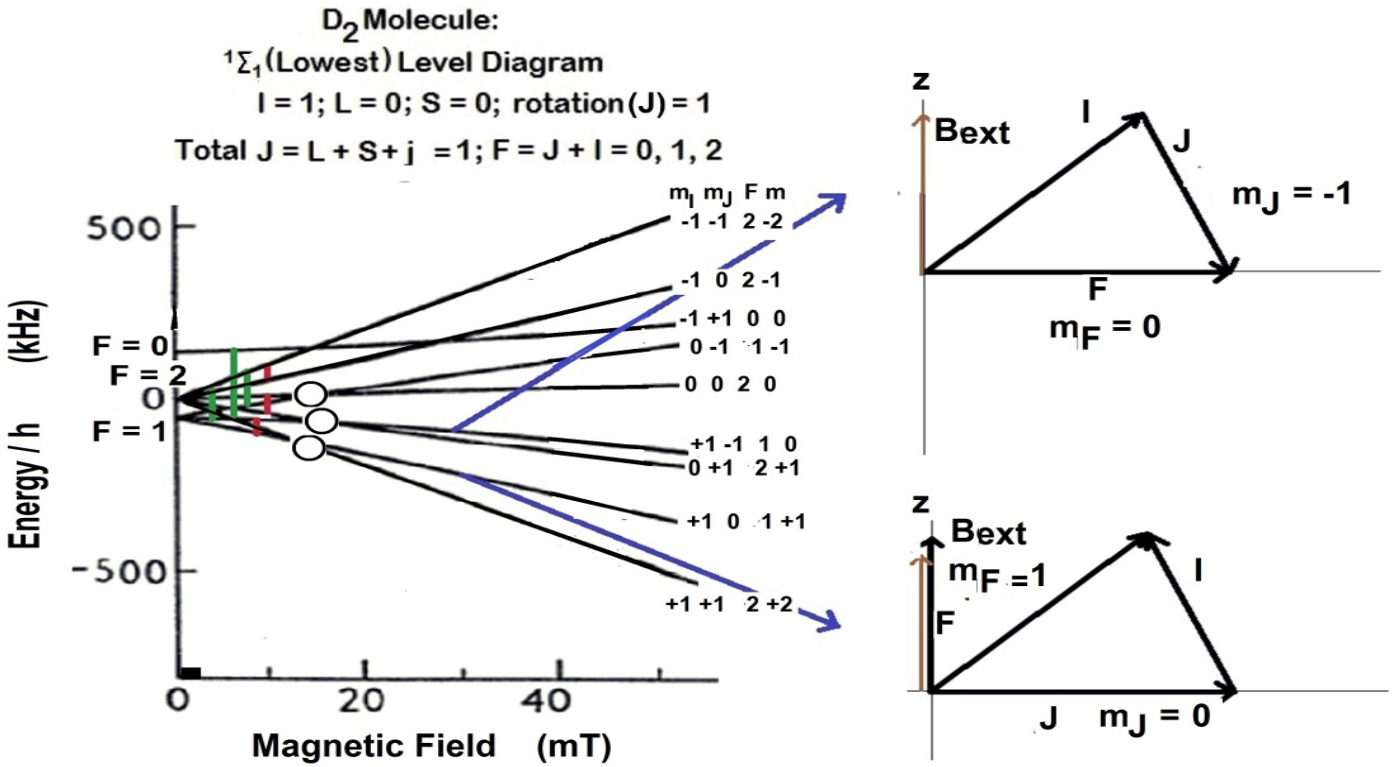
$m_s = +\frac{1}{2}$



$m_s = -\frac{1}{2}$



Energy levels for D_2



Examples of

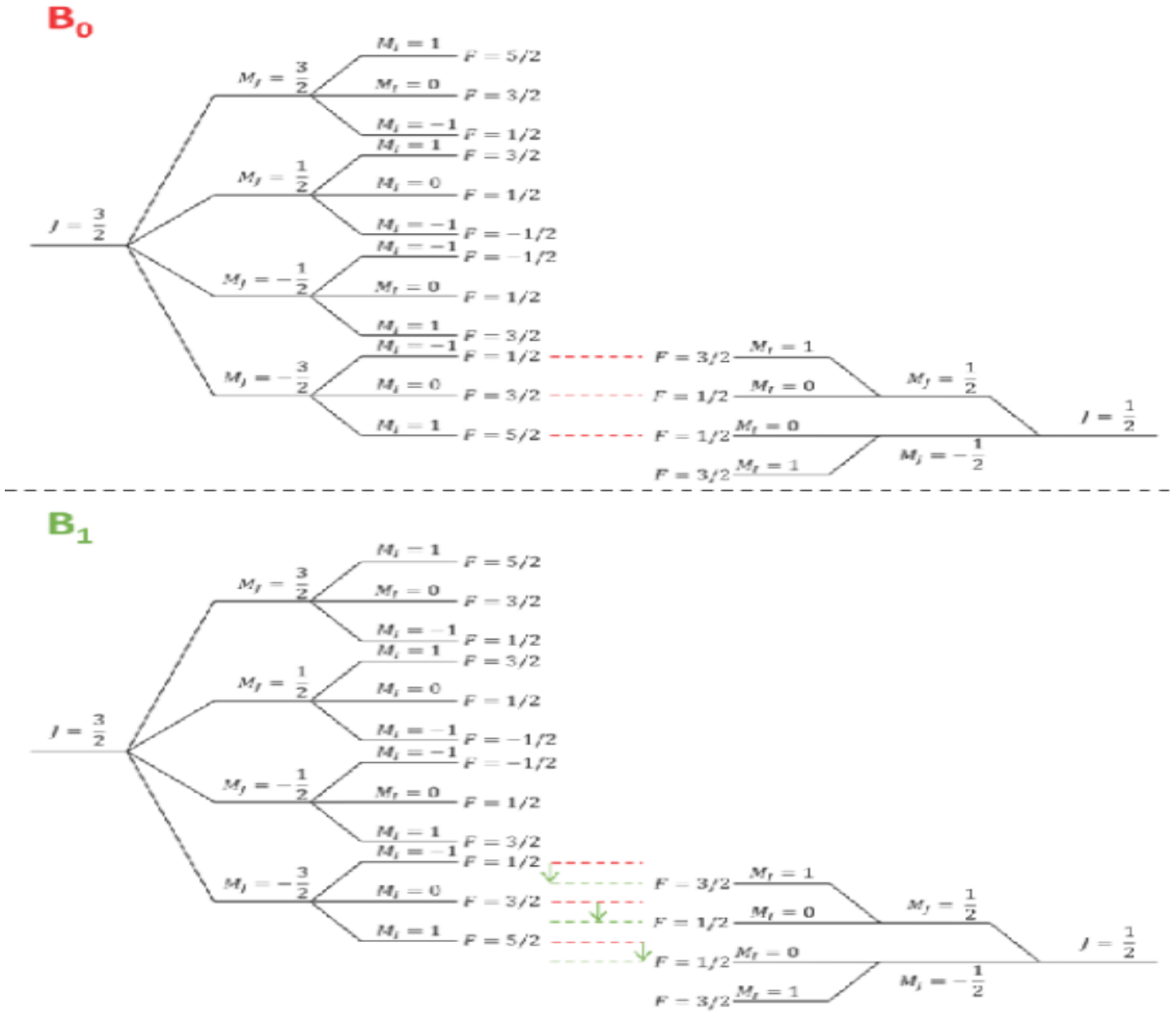
Lower frequency ($\Delta F = 0$)

m_F transitions that change mJ in high field limit

Higher frequency ($\Delta F = \pm 1$)

m_F transitions that change mJ in high field limit

Energy Levels for Radical Pair



Some Examples of Radical Concentration Changes

Usselman et al. show that for rat pulmonary arterial smooth muscle cells (rPASMC). RF exposures at 7MHz and 10μT_{RMS} for 3days in B_{DC}= 45μT lead to both:

1. **Free radical concentration changes:**
    - **45% decreases in O_2^{-*} concentrations**
    - **50% increase in H_2O_2 concentrations**
2. **Enhanced cellular proliferation of up to: (relative to SMF control group)**
    - **40% enhanced cellular proliferation on day 2**
    - **45% enhanced cellular proliferation on day 3**

Usselman RJ, Hill I, Singel DJ, Martino CF (2014) **Spin Biochemistry Modulates Reactive Oxygen Species (ROS) Production by Radio Frequency Magnetic Fields.** PLoS ONE 9(3): e93065.

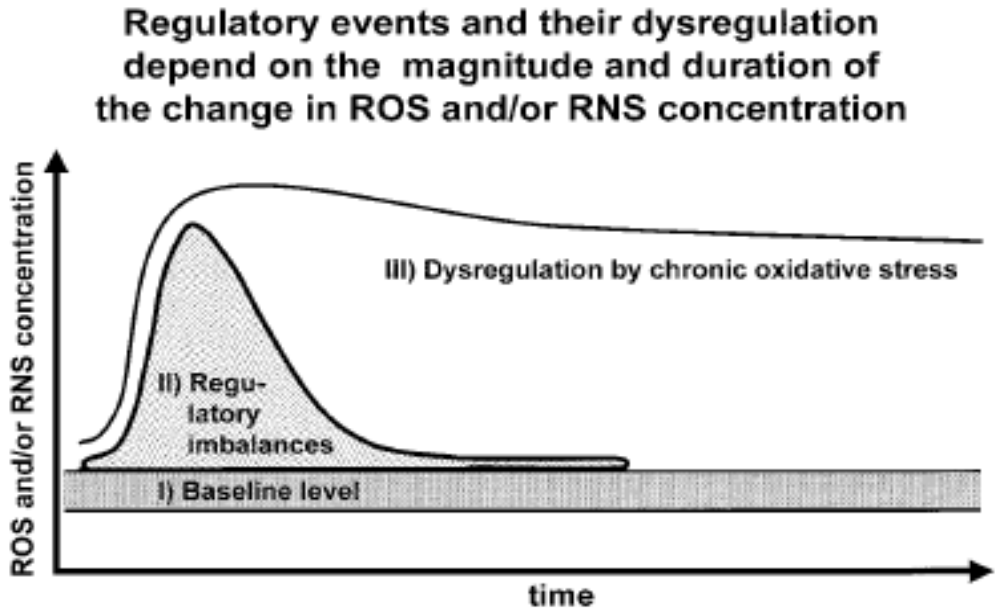
static magnetic field (SMF)

Some Effects of H_2O_2

1. The generation of ROS and H_2O_2 is a <u>normal part of the metabolic process.</u>
2. H_2O_2 is both a signaling molecule and can be destructive by conversion to radicals that lead to the *modifications of DNA and lipids.*
    1. It can stimulate growth in cancer cells at low concentrations
    2. And lead to killing them in high concentrations.
3. ROS produced via normal cell metabolism modify approximately 20,000 bases of DNA per day in a single cell.

Free Radical Concentrations

- **Free Radical concentrations vary by more than an order of magnitude in time as show below.**



- **Normally these concentrations return to the baseline level. Resistive stimulations over long periods of time can lead to a rise in the baseline level we can in turn lead to aging, cancer etc. (Droge 2002)**

Dröge , **Free radicals in the physiological control of cell function**, Physiol Rev. 2002 Jan;82(1):47-95

Why do we not see effects of most of the time?

Feed back and repair processes—*when you cut your finger you do not bleed to death.*

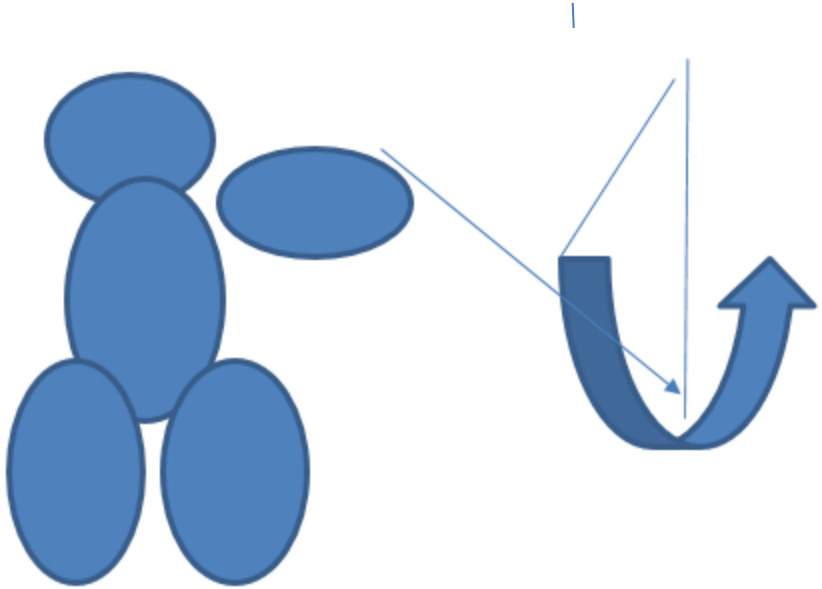
- **When we generate excess reactive oxygen such as H_2O_2 we also generate additional antioxidants.**
- **There is a *time delay* for the generation of the antioxidants and the reduction of H_2O_2 .**

Biological Amplifiers

- Many kinds of biological amplifiers and the energy for most of them comes from the metabolic processes.
- More than 3000 signaling proteins and 15 second messengers.
- Most biological amplifiers contain negative feedback to stabilize the system.

Amplifier with Time Delay in the Feedback

- With a periodic system the sign of the gain depends on the timing with respect to the system.
- An increase in H_2O_2 leads to an increase in the anti-oxidants which leads to a reduction in the H_2O_2



Growth of P815 Mastocvtoma Cells

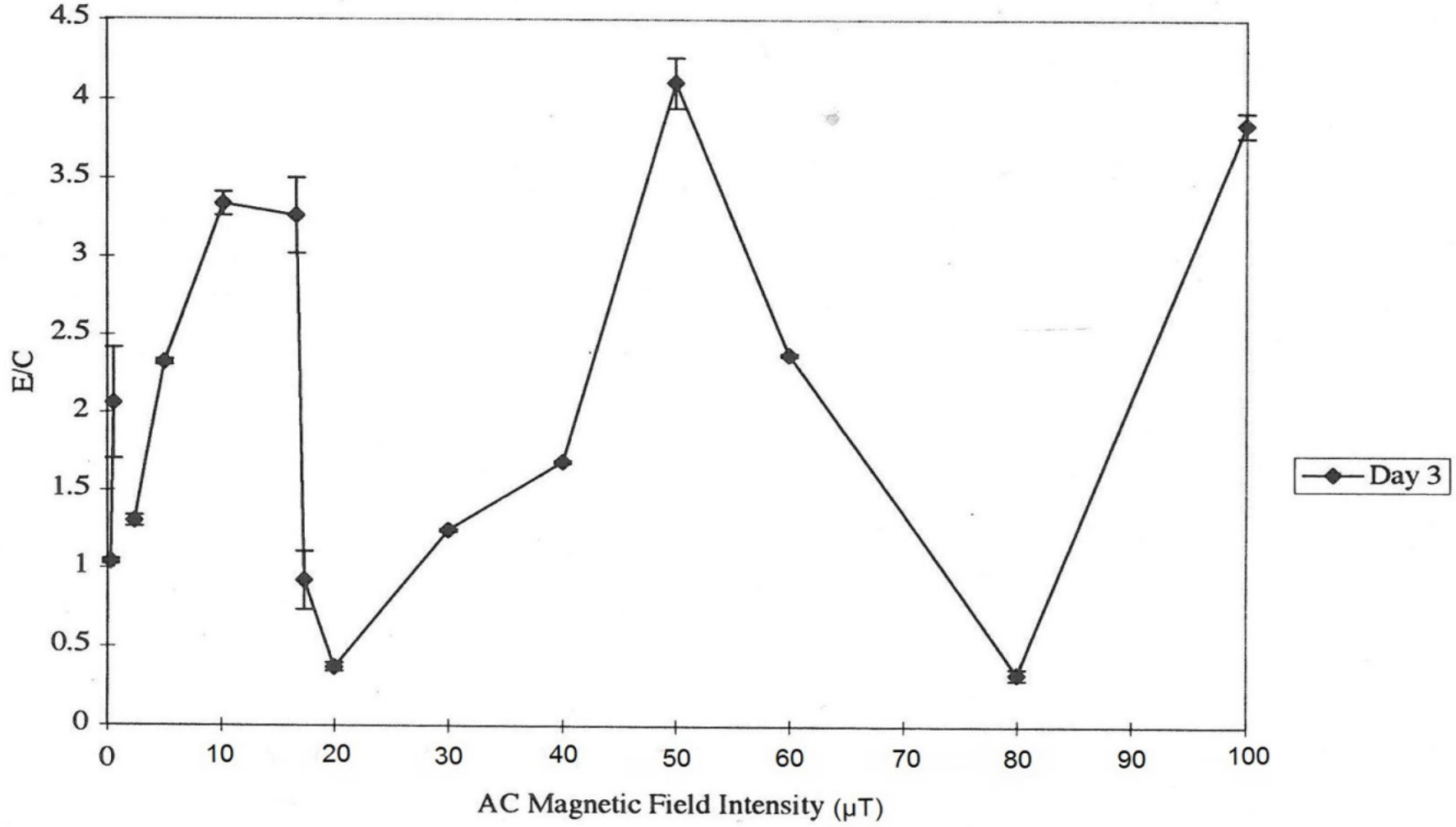


Figure 4.5

Effects of AC Magnetic Field Intensity on Cell Division Rate in Inner Dish

B_{dc}=38μT f= 60Hz **(Bingham 1996)**

On Average, My Temperature Is Just Right!

- 1

Observed Changes in H_2O_2 and Reduction in HT1080 Cell Growth Rates

1. Exposure of **fibrosarcoma HT1080 cells** in vitro to

   10µT at 5MHz and 10MHz at right angles to a SMF of 45µT for 8 h increased H_2O_2 production by 55%

   - ***Reduction*** **in cell count by 30% on day2**
   - **These changes are time dependent.**

*Pablo R. Castello, Iain Hill, Lucas Portelli, Frank Barnes, R.Usselman, Carlos F Martino, "**Inhibition of cellular proliferation and enhancement of hydrogen peroxide production in fibrosarcoma cell line by weak radio frequency magnetic fields**" Bioelectromagnetics Dec **2014** Vol35,pp598-602*

static magnetic field (SMF)

Base Station Exposures

- People living with in 80m of a base station are on the average exposed to higher levels of RFR than those living more than 300m away.
- The analyses of data from the exposed group (n = 40), residing within a perimeter of 80 m of mobile base stations, showed significantly ($p < 0.0001$) higher frequency of **micronuclei** when compared to the control group, residing 300m away from the mobile base station/s
- The analysis of various antioxidants in the plasma of exposed individuals revealed a significant attrition in glutathione (GSH) concentration ($p < 0.01$), activities of catalase (CAT) ($p < 0.001$) and superoxide dismutase (SOD) ($p < 0.001$) and **rise in lipid peroxidation (LOO)** when compared to controls.

Zothansiama, Mary Zosangzuali, Miriam Lalramdinpuii & Ganesh Chandra Jagetia (2017) ***Impact of radiofrequency radiation on DNA damage and antioxidants in peripheral blood lymphocytes of humans residing in the vicinity of mobile phone base stations***, Electromagnetic Biology and Medicine, 36:3, 295-305,
DOI: 10.1080/15368378.2017.1350584

Conclusions

1. **Standards for heating describe short term exposures and biological effects.**
2. **Long term low level magnetic fields can lead to both increases and decreases in the concentration levels of free radicals such as ROS and NOS.**
3. **These effects will be a function of the frequency of the of the AC fields, the angle between the AC and DC magnetic field, the amplitudes and the pulse repetition rates.**
4. **The biological effects of these fields will be a function of time and depend on other stress in the biological system**

Possible Implications

- The Interphone study results show no overall elevated odds ratio (OR) for brain tumors was observed 5–10 years after first phone use. However, in the **10th decile** of recalled cumulative call time >1640 h, the **OR was 1.40** (95% CI 1.03–1.89) for **glioma**, and 1.15 (95%
- CI 0.81–1.62) for meningioma (Cardis et al., 2010).

Possible Implications

- Other studies show increased odds ratios for exposures to RF and low frequencies in the range from **1.5 to 2.**
- The combined number of new cases of brain and other nervous system cancers in the US for men and women per year in 2014 was estimated to be **8.4 new cases per 100,000 per year**. These rates are age adjusted and based on 2010–2014 cases and deaths

Possible Implications

- If we use the data from the interphone study we can estimate that this number would increase by about a factor of 1.4 to about **11.8/ 100,000 for brain tumors among the heaviest cell phone users.** This number might be compared to the number of **traffic fatalities of 10.92 per 100,000** population per year in the US in 2015 (NHTSA).
- Overall this is about **1** additional case per 100,000/year

Relative Risk Factors for Disease Factors

Factor (Cancer type)	Relative Risk	References
Smoking (lung cancer)	10-40	Wynder and Hoffman 1982
Benzene, Occupational exposure (leukemia)	1.5-20	Sandler and Collman 1987
Asbestos, Occupational exposure (lung cancer)	2-6	Fraumeni and Blot 1982
Prenatal X-ray exams (childhood cancer)	2.4	Harvey et.al. 1985
Hair Dye (leukemia)	1.8	Cantor et.al. 1988
Powerlines (childhood cancer)	1.5 – 3	Wertheimer and Leeper 1979, Savitz et.al. 1988
Saccharin (bladder cancer)	1.5-2.6	IARC 1987
Excessive Alcohol (oral cancer)	1.4 -2.3	Tuyns 1982
Coffee (bladder cancer)	1.3-2.6	Morrison and Cole 1982

Source: (J. Lee, Bonneville Power Administration)

Loss of life expectancy and total number of lost days

Cause	Days	Cause	Days
Being unmarried-male / female	3,500 / 1,600	Average job accident	74
Cigarette smoking-male / female	2,250 / 800	Drowning	41
Heart disease	2,100	Falls	39
Being overweight 30% / 20%	1,300 / 900	Fire-burns	27
Being a coal miner	1,100	Generation of electricity	24
Cancer	980	Suffocation	13
Low Socio-economic status	700	Fire arms accidents	11
Living in unfavorable state	500	Natural radiation / From nuclear industry	8 / 0.02
Army in Viet Nam	400	Medical x-rays	6
Smoking Cigar / Pipe	330 / 220	Poisonous gases	7
Job Dangerous / with RF exposure / safe	300 / 40 / 30	Coffee	6
Accidents Motor vehicle / to pedestrians	207 / 37	Oral contraceptives	5
Pneumonia, influenza / Diabetes	141 / 95	Reactor accidents-UCS / RCS	2 / 0.002
Alcohol (US average)	130	PAP exams	-4
Accidents in home	95	Smoke detector in home	-10
Suicide	95	Air bags in car	-50
Legal drug misuse	90	Mobile coronary care unit	-125
Average job accident	74	Safety improvement ‘66-’76	-110