

# **EMF & Health**

## **The Science, or some of it – but when will anyone take any notice?**

**Denis L Henshaw**

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And Scientific Director CwCUK



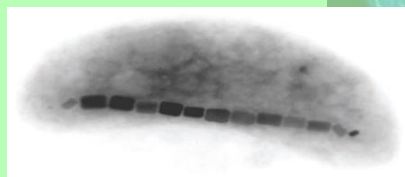
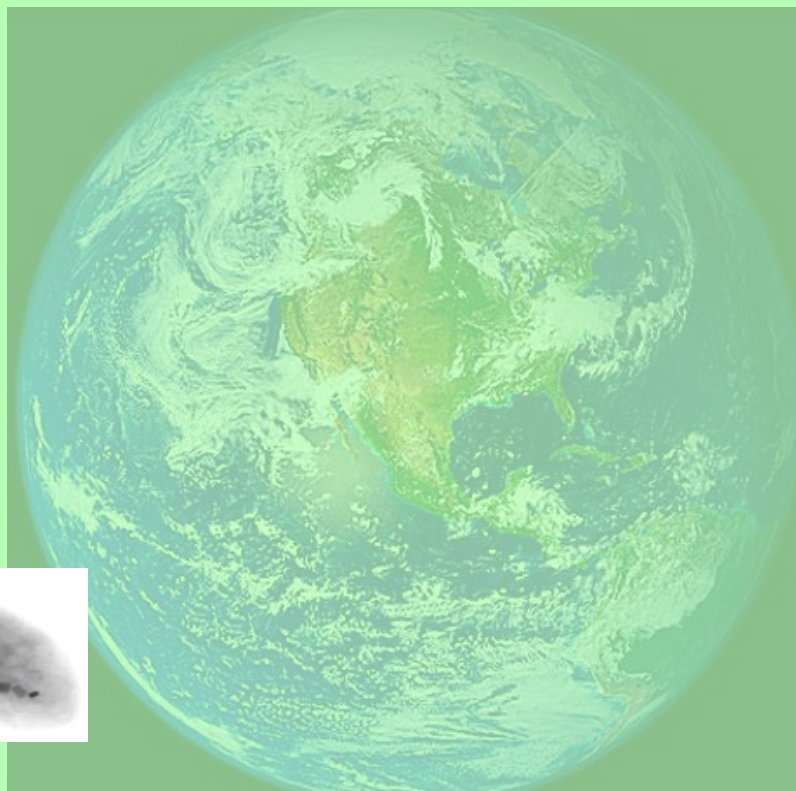
Earth  
forms  
(4.5 bn)

Present  
day

Big  
bang  
(13.2 bn)



← Time (years)



Earth  
forms  
(4.5 bn)

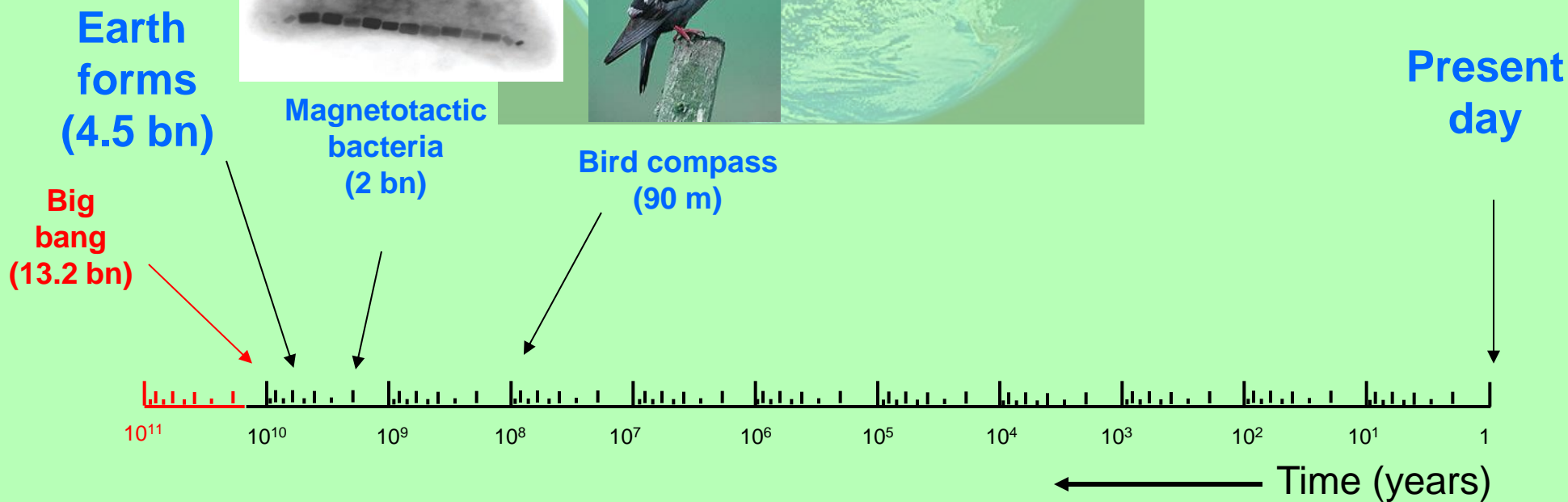
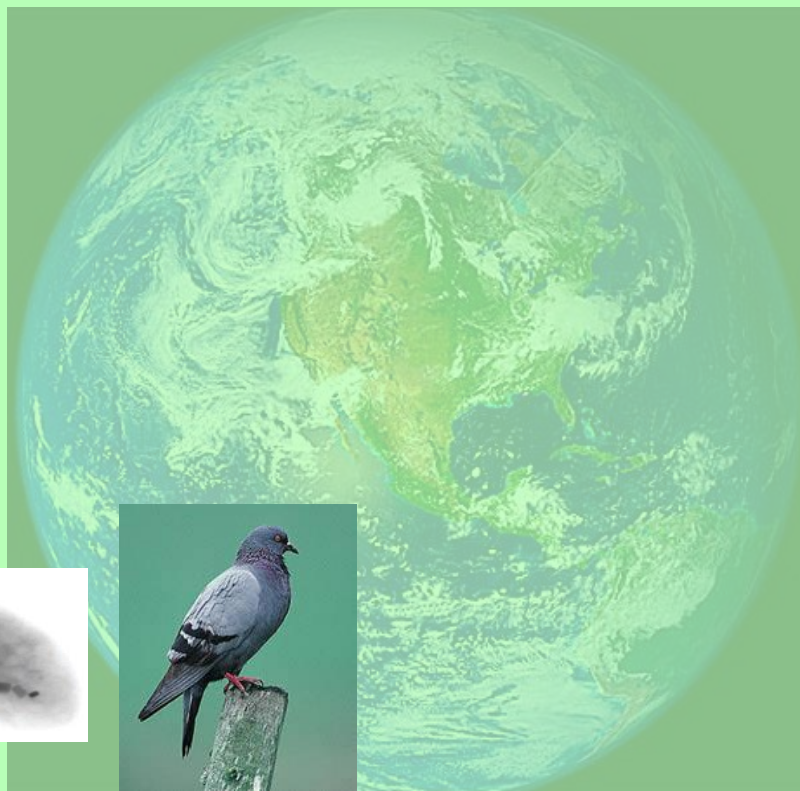
Magnetotactic  
bacteria  
(2 bn)

Big  
bang  
(13.2 bn)

Present  
day

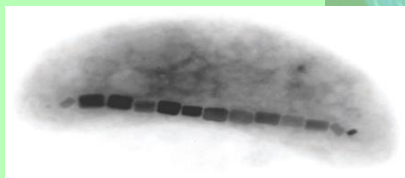


← Time (years)





**Earth  
forms  
(4.5 bn)**



**Magnetotactic  
bacteria  
(2 bn)**



**Bird compass  
(90 m)**



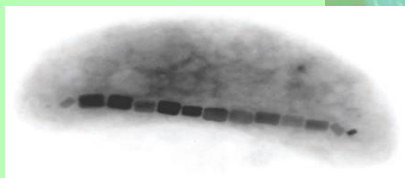
**Early man  
(6 m)**

**Present  
day**

**Big  
bang  
(13.2 bn)**



← Time (years)



**Earth  
forms  
(4.5 bn)**

**Magnetotactic  
bacteria  
(2 bn)**

**Bird compass  
(90 m)**

**Early man  
(6 m)**

**Electrification  
(1894)**

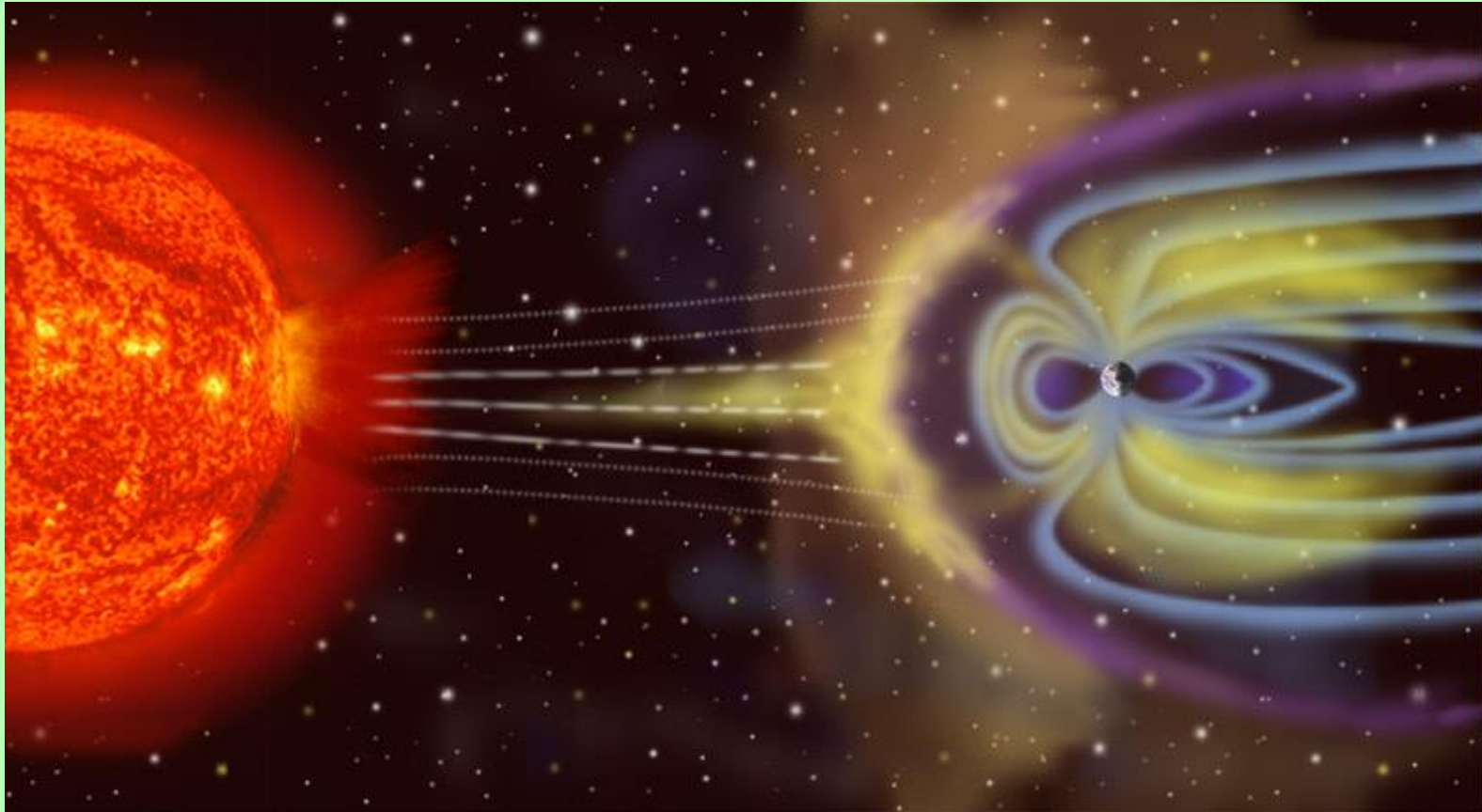
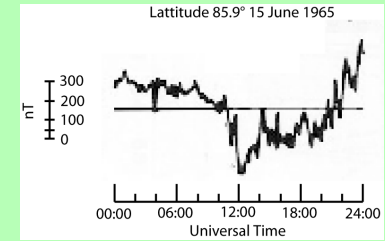
**Present  
day**

**Big  
bang  
(13.2 bn)**



← Time (years)

# Geomagnetic Storms - Arising from charged particles from the sun



Storms of interest last 1–5 days and have a magnitude of about 100 nT. On average 4.6 events per year

**Acute health effects include:** increase in depressive illnesses, melatonin disruption, heart rate variability, blood pressure changes. However, only 10-15% of the population seem affected

# Health effects of GMA

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# Power frequency electric & magnetic fields

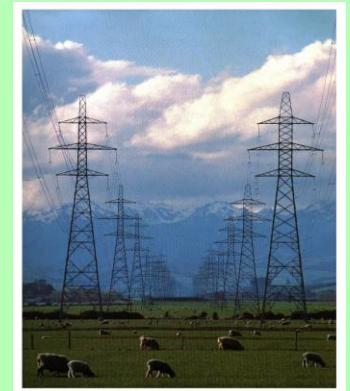
## - especially magnetic fields, MFs



**Appliances:**  
can be tens  
of  $\mu\text{T}$  close to



(Richard Box's 'FIELD' February 2004 Photo: Stuart Bunce, [www.richardbox.com](http://www.richardbox.com))



**Under powerlines MFs can be several  $\mu\text{T}$  or evens tens of  $\mu\text{T}$**

**Doubling of Childhood Leukaemia risk**  
associated with average  $0.3/0.4 \mu\text{T}$

**Average MF home levels  $0.05 \mu\text{T}$**

# Review bodies' assessments of MF association of various diseases.

- IARC has classified Power Frequency MFs as Class 2B – ‘possible carcinogen’.

Disease	IARC <sup>1</sup> 2002	NIEHS 1999 <sup>2</sup>	California 2002	EU: SCENIHR <sup>3</sup> February 2009
1. Childhood Leukaemia	Yes	Yes	Yes	Yes
2. Adult Leukaemia <sup>4</sup>		Yes	Yes	
3. Adult brain cancer <sup>4</sup>			Yes	
4. Miscarriage			Yes	
5. ALS <sup>5</sup>			Yes	
6. Alzheimer's disease				Yes <sup>6</sup>

<sup>1</sup>International Agency for Research on Cancer

<sup>2</sup>US National Institute of Environmental Sciences

<sup>3</sup>EU: Scientific Committee on Emerging and Newly Identified Health Risks:  
Possible effects of Electromagnetic Fields (EMF) on Human Health.

<sup>5</sup>Motor neurone disease

<sup>6</sup>Studies more recently published

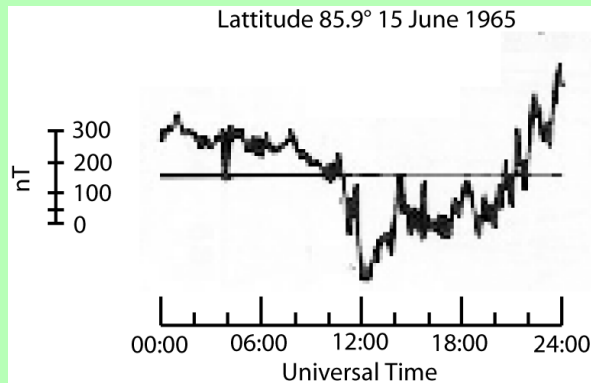
<sup>4</sup>Aggregated data is highly significant:

O'Carroll and Henshaw 2008. Risk Analysis 28:225-234.

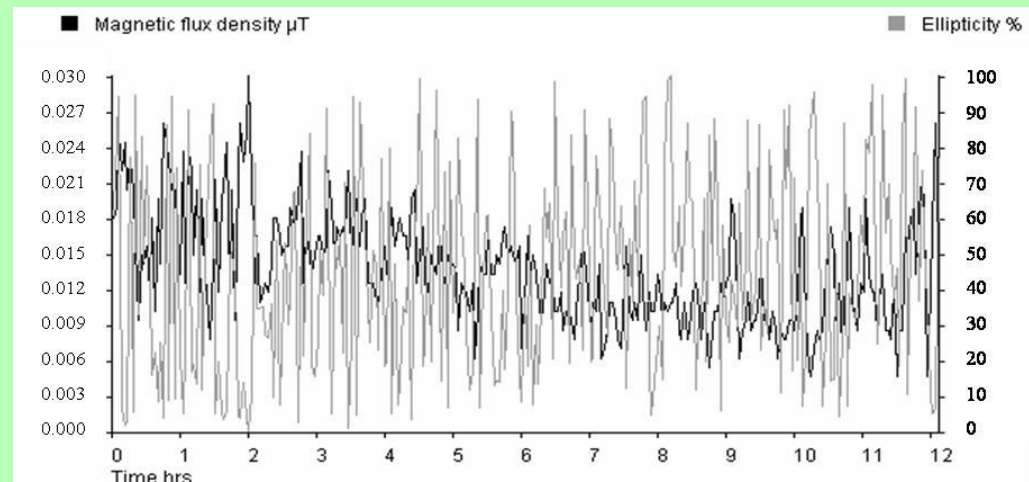
Kheifets et al. 2008. JOEM 50:677-688.

# “Real” magnetic fields are erratic and appear more biologically active than “smooth” fields

## Geomagnetic Storms



“Real” domestic fields [e.g. typical Bristol house] contain fluctuations or transients termed ‘**Dirty Electricity**’



Ainsbury & Henshaw 2006 Phys Med Biol 51:6113–6123

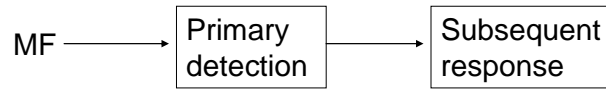
Lee *et al.* (2002) and Li *et al.* (2002) - higher odds ratios for miscarriage for RCM compared to TWA

► Lee, GM. *et al.* *Epidemiology*. 2002; **13**: 21-31.  
Li, D. *et al.* *Epidemiology*. 2002; **13**: 9-20.

## Common question:

Given that we are all exposed to the geomagnetic field of  $50\text{ }\mu\text{T}$ ,  
how can a  $50\text{ Hz } 0.4\text{ }\mu\text{T}$  field make any difference?

The primary physics  
detector, only has to  
detect

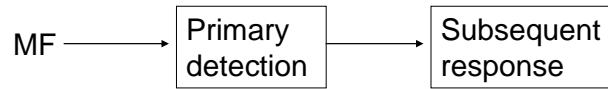


It is the subsequent biological  
response that matters

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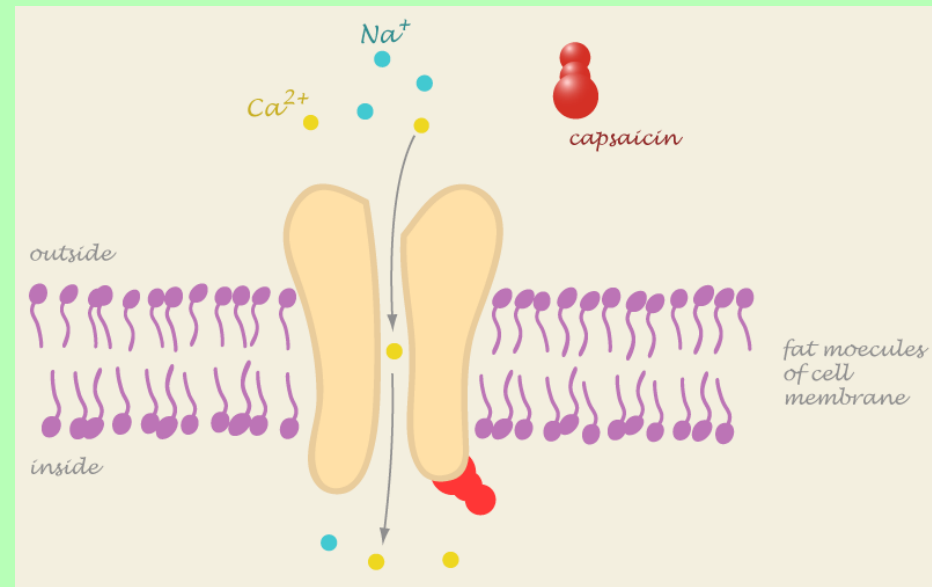
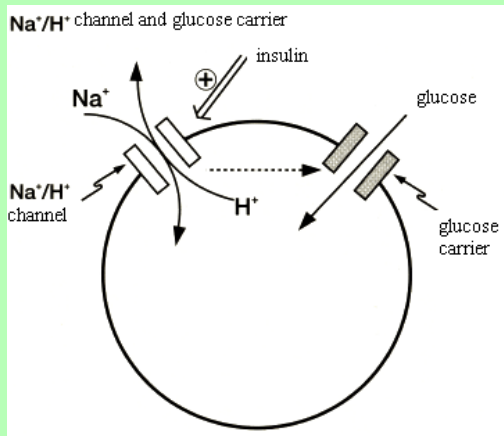


Kate & William



Hunchback of notre Dame

# Low Intensity magnetic fields affect calcium ion efflux from cells

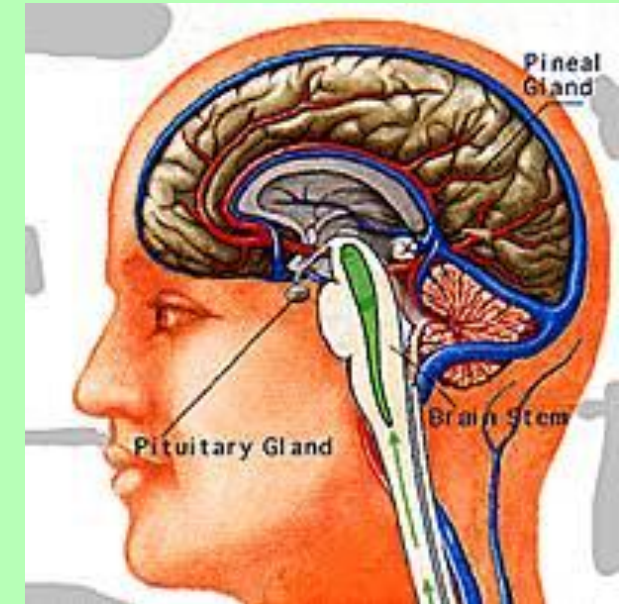


Changes in **calcium efflux from cells** interfere with cell signalling to and from the brain which could explain all of the symptoms of **Electrosensitivity**

# Magnetic fields disrupt nocturnal melatonin

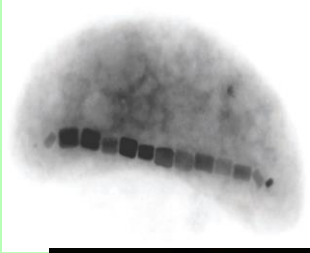
## – could explain many of the EMF health effects

- Melatonin, a powerful natural anti-cancer agent produced in the pineal gland at night
- Disrupted by light-at-night. Night-shift workers have about 50% increased risk of breast cancer
- **IARC 98 (2010) - night-shift work a Class 2A Probable carcinogen**
- **Extensive evidence of magnetic field effects on melatonin, pineal cells, cryptochromes and circadian rhythms in animals and in humans\* and on the human light detection threshold**



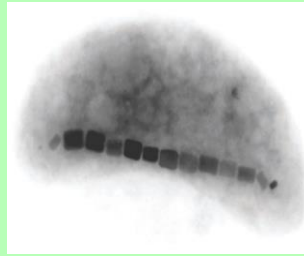
**Two ways in which animals  
sense magnetic fields**

# 1. What do these animals have in common?



All possess biogenic magnetite or other membrane bound iron-mineral particles (magnetosomes) used for navigation

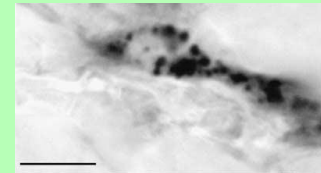
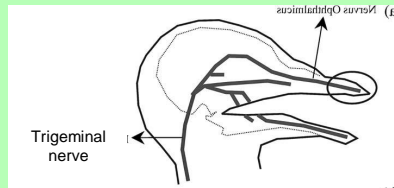
## Magnetotactic bacteria



Chains of magnetite particles

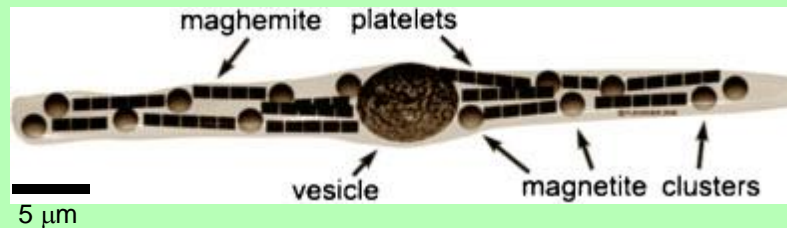


## Pigeons



10  $\mu\text{m}$

Fleissner et al. Naturwissenschaften  
94:631–642 (2007)



Solov'yov & Greiner 2007 Biophys J 93:1493–1509  
- force of 0.2 pN sufficient to excite channels in nerve cell

**Magnetite structures could  
transduce 50 Hz MFs at 0.5  $\mu\text{T}$ :  
Vanderstraeten & Gillis (2010)  
Bioelectromagnetics 31:371-379**

**In pigeons, the inclination sensitivity is 0.02 - 0.17 degrees, down to 0.01  $\mu\text{T}$  (~10 nT) - Gould 2010 Current Biol 21;R226**

# But, the **human brain** also contains magnetite !

- Kirschvink et al. (1992) PNAS 89:7683-87

## Kirschvink et al. found:

- Most grain sizes in the range **10 – 70 nm**, some in the range **90 – 200 nm**, some examples **600 nm** in size.
- **5 million single-domain crystals per gram** for most tissues in the brain and over a **100 million crystals per gram** for pia and dura.
- The larger particles could transduce a 50 Hz field at 0.4  $\mu\text{T}$  (as well as mobile phone frequencies).

## 2. What do these animals have in common?



They have a chemical compass in the eye\*

**\*Note that in salamanders the MF compass is housed in the pineal gland. The gland is also involved in the light-dependent compass in frogs, lizards and some fish**

# How does this chemical compass work?

- Low level magnetic fields can alter chemical reactions between pairs of free radicals\*
- In the animal compass, this is sensed and used to find direction

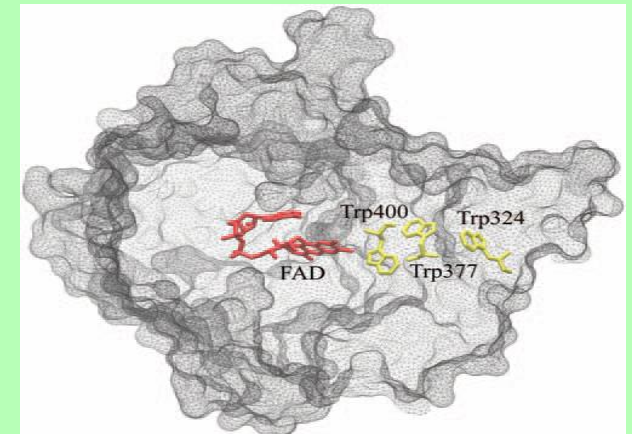
\*Known as the “Radical Pair Mechanism” or RPM

# Where exactly are the magnetic fields sensed?

- They are sensed in biological molecules in the eye called **cryptochromes**
- But cryptochromes are best known for their role in controlling **circadian rhythms (and melatonin) !**
- And **human** cryptochromes have been shown to be **magnetosensitive\***



Schematic view of cryptochrome  
(Solov'yov et al. 2007 Biophys J 92:2711–2726)



~70 kDa (~4 nm dia)

\*Foley, Gegear & Reppert 2011 Nature Comm ncomms1364:

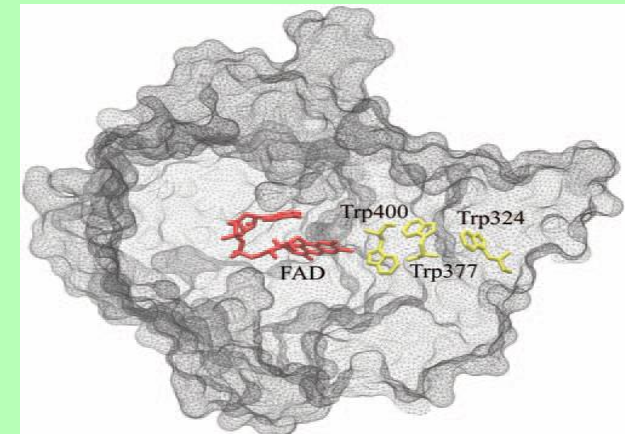
“Human cryptochrome exhibits light-dependent magnetosensitivity”

# How was this all done?

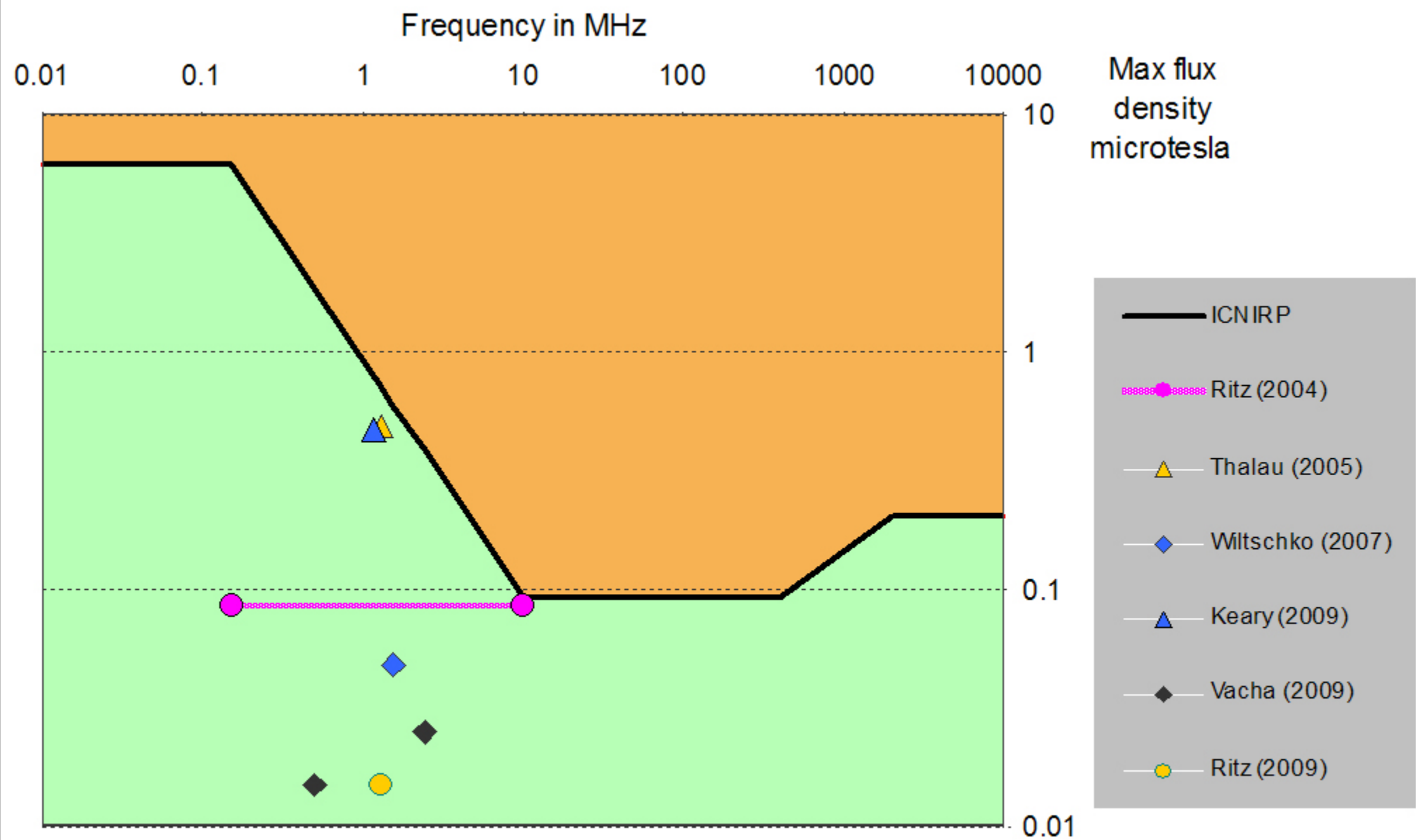
- By using RF fields to interfere with animal navigation (by the RPM process)
- This has since been repeated in **robins, the garden warbler, zebra finches, domestic chickens and the American cockroach**
- RF fields interfere with the animal compass at **remarkably** low levels (~20 nT)



Schematic view of cryptochrome  
(Solov'yov et al. 2007 Biophys J 92:2711–2726)



~70 kDa (~4 nm dia)

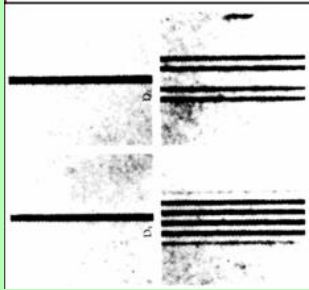


**ICNIRP public guidance flux density levels and reported effects**

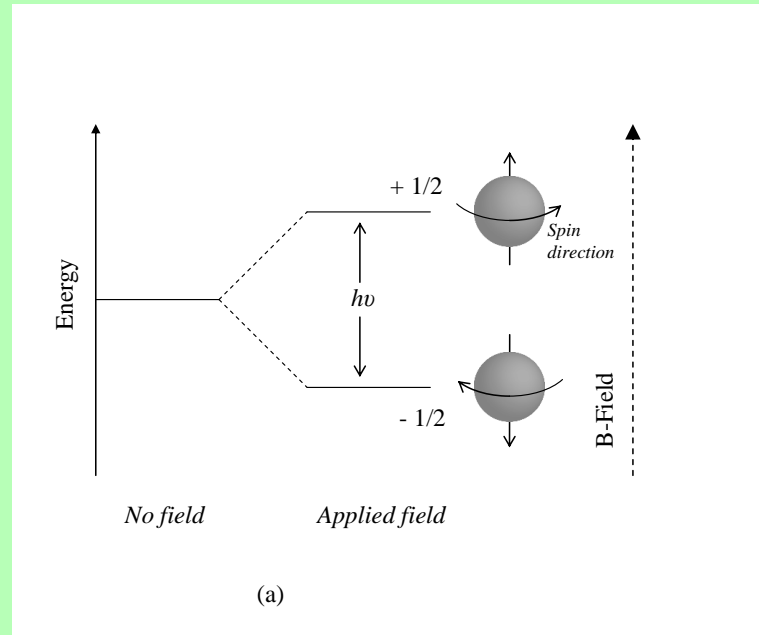
## More on the interaction of magnetic fields with free radicals

In the body, low level magnetic fields can increase the lifetime of free radicals making them more likely to cause biological damage

# How do MFs alter chemical reactions?



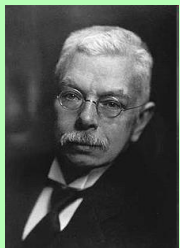
Zeeman Effect 1896  
splitting of spectral lines due to  
the electron spin  
  
- Nobel Prize 1902



In a static MF, electrons split  
into two groups with slightly  
different energy

At the GM field in Leicester, 50  $\mu\text{T}$ :  
-  $h\nu$  is ten million times lower than the thermal energy

Most definitely a non-thermal effect!

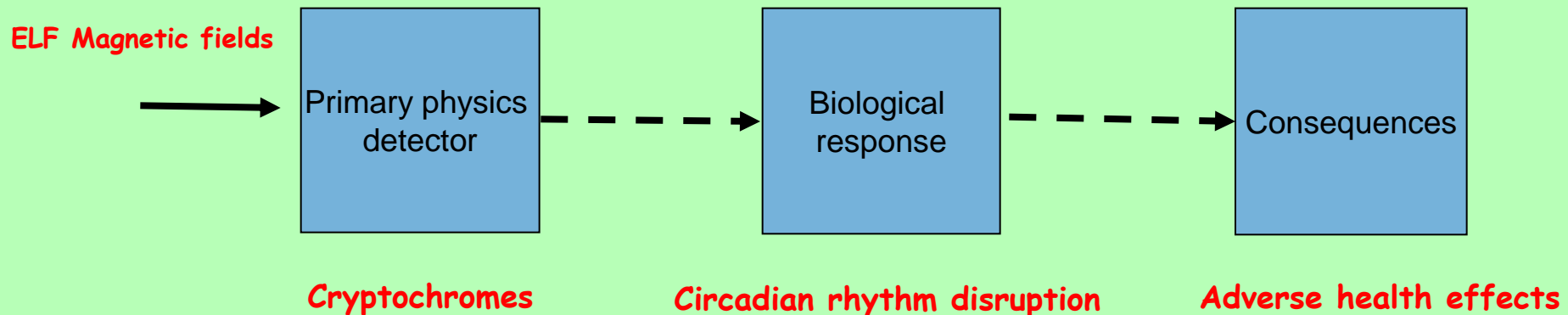


Pieter Zeeman  
(1865-1943)

Get resonant absorption (ESR) at frequency  $\nu$   
 $= 1.4 \text{ MHz at } 50 \mu\text{T}$

# Summary

- Many life forms evolved to detect MFs and use them for navigation; acute adverse health effects are associated with GM storms
  - all below some levels from the electricity supply
- Both magnetite clusters and the RPM can transduce power frequency MFs at common public exposure levels
- The demonstration that **human** cryptochromes are magneto-receptive, has implications for circadian rhythm disruption in humans and one possible model to explain health effects associated with ELF MF exposure



See also full description at:

<http://www.electric-fields.bris.ac.uk>

Front page:

Paper presented at the joint annual meeting of the Association for Radiation Research and The United Kingdom Environmental Mutagen Society, held at the University of Nottingham, June 29 - July 1, 2011. [The interaction of magnetic fields with biological systems – trying to understand the diversity of reported health effects.](#)

# Acknowledgements

Children with Cancer UK