

Jessica Dunlop

From: Nikki Maguire [REDACTED]@maguireroofing.co.uk>
Sent: 23 February 2026 14:58
To: Norwich to Tilbury
Subject: RE: [REDACTED]
Attachments: Draper report 2005.pdf; Leaders not Laggards Oct 2024.pdf; Pylons are not cheaper.xlsx; Prof Denis Henshaw report 2014.pdf; Power line 1998.pdf; Pylons are not cheap.docx; pylons 11.2.26 (002).docx

Categories: CO, Deadline Submission

Dear Georgie,

Please see attached my statement from the Open Floor Hearing on the 12th February 2026 at Orsett, Essex. Please also see attached relevant information:-

Report written by Pylons East Anglia called, 'Leaders not Laggards' showing better options and why coordinating offshore saves cost and infrastructure on land – which National Grid themselves advocate (please copy link to watch National Grid video, which they have since removed from social media

[Scaling up calculations of Hinkley point, called Pylons are NOT cheap/cheaper.](https://www.google.com/search?q=national+grid+offshore+grid+video+&sca_esv=b32b4b207e952da5&sxsrf=ANbL-n4zL4kRv74U8C8XbhDOKHxof9odcw%3A1771852368216&source=hp&ei=UfKcacmkC6rOhbIPwI7l8Q0&iflsg=AfDpzrgAAAAAaZxgYK_CGekodz6TZw1wxfpHBSlNadXY&ved=0ahUKEwjJlC42O-SAXuqZ0EAHUBHOd4Q4dUDCCA&uact=5&oq=national+grid+offshore+grid+video+&gs_lp=Egdnd3Mtd2l6liJuYXRpb25hbCBncmlklG9mZnNob3JlIGdyaWQgdmlkZW8gMgUQIRigATIFECEYnwUyBRAhGJ8FMgUQIRifBUirSVDaBljcQnABeACQAQCYAWygAeQVqgEEMzAuNLgBA8gBAPgBAZgCI6AC0xaoAgrCAgcQlxgnGOoCwglKECMYgAQYJxiKBclCEBAuGIAEGMcBGccYigUYrwHCAgsQABiABBiRAhiKBclCDhAuGIAEGLEDGNEDGMcBwglLEAAygAQYsQMYgwHCAggQABiABBixA8ICCAuGIAEGLEDGIMBwglFEAAygATCAhEQLhiABBixAxjRAXiDARjHAcICDhAuGIAEGLEDGIMBGIoFwglFEC4YgATCAggQLhiABBixA8ICERAUgIAEGJECGMcBGloFGK8BwglOEC4YgAQYsQMYxwEYrwHCAgYQABgWGB7CAgsQABiABBIGAXiKBclCBxAhGKABGAqYAwXxBW-MYflu6qjykgcEMzAuNaAH1ocCsgcEMjkuNbgHzRbCBwY2LjL2LjPIB0KACAA&sclient=gws-wiz#fpstate=ive&vld=cid:86a51c2e,vid:dL5rbXtAPVI,st:0).</p></div><div data-bbox=)

Draper report 2005
Prof Denis Henshaw 2014
Power lines 1998

I have been unable to find any reports or have had any answers from National Grid regarding living near pylons with a pacemaker (TB31, TB32, TB33, TB34 are very close to my property and will fall into the above reports with leukaemia, cancer and brain tumours).

I very much look forward to hearing from you in due course.

Kindest Regards,

Nikki Maguire
[REDACTED]

🕒 This article is more than 20 years old

Power cables linked to cancer

John Carvel, *social affairs editor*

Fri 3 Jun 2005 11.49 BST

 Prefer the Guardian on Google

Children living near high-voltage power lines are substantially more likely to develop leukaemia, researchers from Oxford University and the national electricity grid report today in the British Medical Journal.

Those living within 200 metres of the overhead cables were 70% more likely to develop the disease than similar children living more than 600 metres away. And those living between 200 and 600 metres away had a 20% increased risk.

The results were based on an eight-year investigation into the home circumstances of the 9,700 children who developed leukaemia in England and Wales between 1962 and 1995. Since the 1950s the National Grid has erected more than 4,000 miles of high-voltage overhead lines to carry electricity, usually at 275,000 volts or more.

The researchers found 64 of the children lived at birth within 200 metres of a power line and 258 lived between 200 and 600 metres away. The statistics suggested that living in close proximity to a power line might be linked in some way to five cases of leukaemia a year.

But Gerald Draper, leader of the study team from the Oxford childhood cancer research group, said the research had not found any scientifically valid causal link.

Earlier research showed that high-voltage lines could give out a weak magnetic field extending for about 60 metres. This was equivalent to about 1% of the earth's existing magnetic field. It could not explain why the risk of leukaemia was as great for a child living nearly 200 metres from a line as for one living directly beneath one.

Dr Draper said: "It may not be the effect of power lines at all. It may be something to do with the kind of areas where power lines are located, or the

sort of people who live in these areas."

About 4% of people in England and Wales live within 600 metres of a high-voltage line.

John Swanson, a scientific adviser to National Grid Transco and one of the authors of the report, said: "We have strengthened the evidence that something is happening, but we haven't made any connection about why it is happening: if only we had."

Dr Swanson added that he would not let proximity to power lines deter him from a property. But if all things were equal and another property was available further away, he would find that preferable.

Another major research programme, the UK Childhood Cancer Study, suggested in April that most cases of childhood leukaemia had their origins before birth and might be triggered by infections early in life. It said there was minimal risk from electrical installations or magnetic field levels. Children in daycare before the age of one were less likely to develop leukaemia, perhaps because exposure to minor infections might prime the immune system, it suggested.

John Toy, Cancer Research UK's medical director, said people living near power lines had no need to panic. "The triggers that cause childhood leukaemia are most likely a random course of events over which a parent has no control," Professor Toy said.

But Eddie O'Gorman, chairman of the charity Children with Leukaemia, said: "There is now a clear case for immediate government action. Planning controls must be introduced to stop houses and schools being built close to high-voltage overhead power lines."

A Department of [Health](#) spokeswoman said: "At this stage, research has not proved that power lines cause leukaemia in children."

However, the department had already set up a group of experts to consider whether there was any need "to develop precautionary measures to reduce exposures to electromagnetic fields".

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LEADERS NOT LAGGARDS

October 2024

Let's learn from best practice overseas and make it a GREAT grid upgrade.

Introduction

We can have a grid upgrade that is good for consumers, communities, and the environment, but here in the UK, sadly the discussions about how to achieve this leave much to be desired, focusing solely on pylons, and terms such as NIMBY, blocker and obstructionist are bandied about all too liberally. It is essential instead to have a serious national conversation about how to achieve a **great** grid upgrade.

A Clean Power 2030 review^[1] is under way. Work on the national Strategic Spatial Energy Plan^[2] has been commissioned. And the Planning and Infrastructure Bill will, in due course, wend its way through Parliament.

Let's make sure that we learn from the many other countries which recognise that there are many ways to upgrade the grid.

Take the USA. It is a requirement that the existing grid be upgraded before new infrastructure is built. Look also at Germany – pylons are a last resort, and high voltage direct current undergrounding is preferred. And see how our North Sea neighbours are creating an integrated offshore grid instead of the damaging and expensive point-to-point approach of the UK.

To ensure the best outcome, three things need to change:

i. Pylons the last resort.

National Policy Statements (England) should favour upgrading the existing grid, offshore integration, and HVDC undergrounding ahead of overhead lines (i.e. removing the strong starting presumption in favour of pylons).

ii. Follow Treasury guidance for best outcomes.

Treasury Green Book guidance must be adhered to by transmission operators and enforced by Ofgem, the Planning Inspectorate and the Secretary of State. It is mandatory, after all.

iii. Compensation - NOT benefits.

There must be full compensation for homeowners and businesses when grid projects go ahead. Transmission operators must have 'Discretionary Purchase Schemes', as other Statutory Undertakers do. 'Community benefits' must be in addition to compensation, not instead of it.

The UK has so much to learn. We should aim to be a leader, not a laggard.

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1. Nuts & bolts - use what we have

If you were told you could double transmission capacity^[3] without building a single new pylon, you would choose that, surely?

The United States recognises that the most efficient, cost-effective, and least damaging way to upgrade the grid is to optimise the existing grid before building new infrastructure.

In May this year, an Order known as Federal Energy Regulatory Commission 1920^[4], was launched. This Order mandates the use of Alternative Transmission Technologies (ATTs) such as dynamic line ratings, advanced power flow controls, advanced conductors and transmission switching before building costly and damaging new infrastructure.

Reconductoring alone offers huge benefits. New technologies enable two to three times more power to be carried over existing infrastructure. It has been found to be a particularly promising, viable and ‘*cost-effective, implementation-ready solution that is deployable to scale*^[5].

Also in the United States, in California a private developer proposed converting an existing 500kV line to HVDC instead of building a new 180-mile line as originally proposed by the System Operator. This alternative proposal would re-use existing towers, conductors and insulators and increase the capacity from 1.3GW to 3.5GW. Costs, environmental and planning barriers would all be materially reduced.

Why would you not choose a solution that allows you to build additional capacity into the existing system to ‘unlock otherwise stranded clean energy, especially sources available near existing grid infrastructure, helping meet electricity demand and contributing to grid decarbonization’?

This approach should be made a mandatory requirement here, and National Policy Statement EN-5 must be updated to reflect a requirement to use existing infrastructure first.

2. Going underground (HVDC)

If you could keep communities happy, and reduce costs by using the most up-to-date undergrounding technology instead of pylons, you'd choose that option, surely?

Unlike in the UK, in Germany preference is given by law (in the Federal Requirements Plan) to underground cables[6]. Germany favours underground cables to mitigate public opposition, protect natural landscapes, and address concerns about the visual and environmental impact of overhead lines.

High-voltage direct current (HVDC) transmission lines are often the chosen technology. HVDC benefits include reduced transmission losses, greater stability and control, lower strength EMF, fewer cables, and cost effectiveness over long distances. HVDC cables require far less space and narrower trenches than High Voltage Alternating Current (HVAC) and cause considerably less disruption to residents during installation.

The German approach has been essential in gaining public support for large-scale infrastructure projects. Prysmian Group[7], for example, uses powerful ± 525 kV HVDC underground cable technology. Amprion (a German transmission operator) takes an innovative approach which demonstrates that the use of one 525kV plastic-insulated cable system carrying 2GW of power, can reduce the trench size still further. Cable-ploughing is also an effective way to reduce costs and physical damage and speed up undergrounding.

Here in the UK, two reports published in 2024 demonstrate that underground HVDC is a very cost-effective solution, better than overhead lines.

The first was the East Anglia Network Study[8] for the National Energy System Operator[9]. It found a £600m saving in an option using underground HVDC instead of overhead lines if a completion date of 2034 was selected instead of 2030. Given that an independent report[10] for the county councils of Essex, Suffolk and Norfolk established that the regional grid has sufficient capacity

until 2034, it surely makes sense to select the most cost-effective and more popular option instead of the reviled and damaging overhead line proposal?

The second was a National Grid document^[11] for Eastern Green Link. It found that overhead line technology was 'not considered to meet the identified need for additional transmission system capacity'. Reasons given included:

- Power flows on AC transmission system circuits cannot be controlled to the same extent as can be achieved using HVDC connections.
- The required capacity HVDC links over the proposed distance have comparable capital costs, but much lower lifetime costs than the alternative onshore AC option in this case.
- ...delivery of an onshore solution with a long route length, carries much higher delivery risk than the HVDC reinforcement proposals.
- The use of overhead lines is not considered to be feasible because they cannot be delivered by 2030.

One of the criticisms of HVDC is that it is best for long distance point-to-point connections without mid-way connection points. Amprion has overcome this in Germany and is constructing the world's first hybrid, multi-terminal HVDC link, between Lower Saxony and Baden-Württemberg.

If you have heard previously that undergrounding is five to ten times more expensive than pylons, that is because it relates to High Voltage Alternating Current (HVAC) undergrounding, as preferred by National Grid. Not only is AC undergrounding expensive, but it is also extraordinarily destructive, requiring a construction swathe 120metres wide^[12] (sometimes up to 220metres).

And finally, it is little known that **underground cables do not always require planning consent**. It is for A Secretary of State to decide whether a proposal should be designated as a nationally significant infrastructure project.

Protections for the environment, heritage and communities are needed but undergrounding could be significantly faster than overhead lines.

Underground HVDC should be the preferred option, not overhead lines.

3. Offshore coordination

If you could halve transmission infrastructure, save £2 billion (in the North Sea alone) and reduce harm to the environment and communities, you'd choose this approach. surely?

Study after study has highlighted the benefits of an integrated offshore grid.

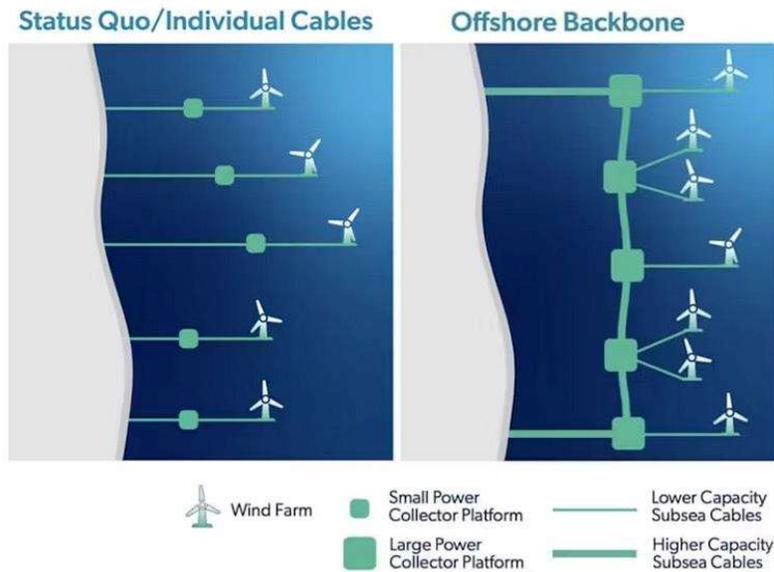
Government even refers to one of these studies in National Policy Statement EN-5, stating, *“The coordinated approach is likely to provide the highest degree of consumer, environmental and community benefits.”*

Yet despite this, our UK offshore model still runs on a **point-to-point** or **radial** approach. Every offshore wind farm or interconnector operates in isolation. That's bad for consumers, the environment, and communities and bad for the operation of the grid.

An integrated offshore grid would connect offshore wind power in the North Sea, keeping it offshore as long as possible. Wind farms would be linked to energy islands and interconnectors. Landing points should be at brownfield sites close to where power is consumed. In the East of England this saves £2billion versus the current piecemeal approach & reduces overall infrastructure by 50%.

Details of the £2bn saving and other benefits were set out in National Grid ESO's 2020 report, and this year an academic study [\[13\]](#) confirmed cost savings through integration. Integration savings were previously set out in the 2015 Integrated Offshore Transmission Project East[\[14\]](#). This report built on the Crown Estate's and National Grid's 2011 Offshore Future Network Transmission System review. It was reported[\[15\]](#) that in 2011, *“National Grid has shown an offshore network would be more cost effective, reduce the number of cable landing sites and minimise onshore reinforcement requirements”*. (Curiously, this study has disappeared from all previously published links on the Crown Estate, National Grid, and other pages).

Lest there be any remaining doubt about the benefits of offshore integration, this approach is also being considered in East Coast United States. Here, ten states and the U.S. Department of Energy [16] are working on a potentially transformative solution which coordinates wind power offshore. This schematic [17] illustrates perfectly how an integrated approach reduces infrastructure:



As here in the UK, there is plenty of research that indicates that an offshore grid would help to reduce challenges of building transmission lines on land and reduce costs.

This includes the Atlantic Offshore Wind Transmission Study [18], which found that offshore coordination results in:

- Reduced curtailment, reduced usage of higher-cost generators, and contributions to reliability.
- Greater grid reliability (by enabling resource adequacy and helping manage the unexpected loss of grid components (contingencies)).
- Benefits outweighing the costs, often by a ratio of 2 to 1 or more. Offshore networks with interregional interlinks provide the highest value.

A second study by Brattle[19] found that, “*starting proactive planning for these long-term offshore wind generation needs now likely will save U.S. consumers at least \$20 billion and reduce environmental and community impacts by 50%. Doing so will also support the timely achievement of policy goals, increase reliability, lower development, and investment risks, increase energy independence, and improve climate resilience.*” And it notes an “*urgent case for proactively and holistically planning transmission solutions for the nation’s increasingly ambitious offshore wind goals.*”

For full integration, HVDC switches will be required, in case of grid failure. In Germany, Amprion is already cracking on with the job of planning for coordination offshore with research into these switches. The company recognises the huge number of benefits of integration, saying grid operators can, “*respond to the congestion situation flexibly when integrating the power from offshore wind farms. If the offshore grid integration systems are not fully utilised, additional transmission capacity can be provided thanks to the offshore interconnectivity. This lets onshore grid congestion be defused or remedied effectively, avoiding the need for redispatching.*”

Given that the UK now has around 15GW of offshore wind, but apparently needs to achieve 50GW to meet targets, there is simply no option but to coordinate offshore. Every point-to-point project that is connected simply brings more environmental and socio-economic damage, and great cost to consumers.

There is no excuse for our government not to ensure that all necessary steps are taken for early coordination of more wind farms into offshore platforms and/or interconnectors (as with the offshore hybrid assets programme).

4. Pylons, the last resort

If you knew all of the above and that pylons are not as cheap as government and National Grid would have you believe, you would insist that they are the last resort, surely?

Pylons must be the last resort, only considered once all the options above have been exhausted.

Pylons are not cheap

Pylons projects, contrary to public belief and official pronouncement, are not cheap.

Our own analysis[20] shows that one project, the 180km Norwich to Tilbury[21] proposal, will cost between four and eight times more than National Grid's stated cost.

That is because:

- When compared with other overhead line projects, Norwich to Tilbury is unusually cheap – despite it being National Grid's longest and riskiest project.
- Socio-economic and natural capital impact has not been presented as it should be under Treasury Green Book guidance.
- Contrary to Green Book guidance, instead of the required 40% contingency, only 10% contingency has been included.
- Biodiversity Net Gain costs have not been included and, depending on how 10% net gain is achieved (voluntary agreements, compulsory purchase or purchase of statutory credits), it could cost hundreds of millions of pounds.
- Community Benefits have not been included. Government has not published details of how the benefits scheme will work but, based on proposals under the previous government, 'pounds for pylons' will cost hundreds of millions of pounds.

What's wrong with new pylons?

- Millions of trees and hedgerows will be uprooted.
- The setting of heritage assets will be destroyed and countryside views painted by Constable, Munnings & Gainsborough will be lost.
- Power lines kill birds (including 177 swan deaths in just one incident)
- Houses become unsaleable without huge discounts; mortgages refused.
- Businesses, including farms and tourist businesses affected.
- Damage to soils & farmland, reducing food security.
- A motorway grade haul road the entire length of the project requires millions of tonnes of aggregate.
- A swathe of destruction 40- to 80-metres wide for pylons and over 120-metres wide for the underground sections in the National Landscape and Waveney Valley
- Concrete for the 550 pylon bases; steel for the 550 pylons
- Countless HGV movements
- Soil carbon release

Less intrusive towers

In the rare scenarios when pylons are the only appropriate technology, steps MUST be taken to minimise their impact. For example, TS Conductor (a US company part-owned by National Grid) builds strong, lightweight, 'low sag' conductors which allow three times the power transmission of traditional conductors. If new towers are needed, the TS Conductor technology requires fewer and shorter pylons. Not only does that reduce the impact, but it also saves money and builds in more capacity for the future. TS Conductor is developing compact pylons for direct-current overhead lines.

National Grid must move on from using the same, 50-metre high, lattice towers it has been using for seventy years.

Costings must be transparent and like-for-like, and follow Treasury Green Book guidance.

5. Compensation

If your business or home is financially impacted by a national infrastructure project, you expect compensation, right?

When a transmission project takes place, residents, landowners, and business owners must be compensated for any financial impact arising from grid infrastructure.

So-called 'Community Benefits' barely scratch the surface and will be resisted. Benefits are not compensation.

Full equivalence must be paid both inside and outside the draft orders (online and offline). No-one should be out of pocket.

National Grid must be required to have a Discretionary Purchase Scheme[\[22\]](#) as other Statutory Providers do.

Conclusion: let's be leaders not laggards

We call for the adoption of modern grid-enhancing technologies, offshore integration, and underground HVDC cables to avoid the negative impacts of pylons. These alternatives are cheaper, better for the environment, and more popular with communities.

The nation's grid needs upgrading. Yet it must be done sensitively, in the best way possible for communities, consumers, and the environment.

Our own region faces 180km of pylons (with two short stretches of AC undergrounding) across the three beautiful counties of Norfolk, Suffolk, and Essex. These new pylons will cause terrible harm to our region's wildlife and habitats, history and heritage, landscapes, and businesses. The project, proposed by National Grid Electricity Transmission, is already causing huge heartache and mental health issues.

We are fed up with hearing that pylons are the only way or the cheapest way. That is simply not true. Better and cheaper ways include an integrated offshore grid, underground HVDC cables and upgrading the existing grid.

We seek a revision of the National Policy Statements, enforcement of adherence to Treasury Green Book guidance and full compensation for those affected by grid projects.

We need a GREAT grid upgrade that's good for everyone and the environment.

Essex Suffolk Norfolk Pylons action group

www.pylonseastanglia.co.uk

pylons180@gmail.com

Queries to Rosie Pearson

SOURCES

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- [5] [GridLab_2035-Reconductoring-Technical-Report.pdf \(2035report.com\)](#) and <https://www.smart-energy.com/industry-sectors/energy-grid-management/how-advanced-conductors-solve-four-key-grid-challenges/>
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- [10] [n2t-the-hiorns-report \(suffolk.gov.uk\)](#)
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- [13] [download \(neso.energy\)](#) & Benefits of an integrated power and hydrogen offshore grid in a net-zero North Sea energy system (Published in Advances in Applied Energy 7, 2022, 100097)
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Power Lines (Electromagnetic Fields)

HC Deb 29 October 1998 vol 318 cc530-8

Motion made, and Question proposed, That this House do now adjourn.—[Mr. Kevin Hughes.]

Miss Anne McIntosh (Vale of York) I am grateful for the opportunity to have this debate. I am sure that the House will join me in congratulating the Minister for Public Health, who has today been appointed a Privy Councillor.

8.11.pm

I shall explore the dangers to health caused by exposure to electromagnetic fields near power lines. In preparing for the debate, I was immensely grateful to be able to consult the work of Professor Denis Henshaw at the university of Bristol, which is entitled "Mechanisms of increased exposure to environmental pollutant aerosols near high voltage powerlines"; the work of Professor Mike O'Carroll, emeritus professor at the university of Sunderland and chairman of Rural England Versus Overhead Line Transmission, otherwise known as REVOLT; and the report of the working group of the United States National Institute of Environmental Health Sciences entitled "Assessment of Health Effects from Exposure to Power-Line Frequency Electric and Magnetic Fields".

All that work proves that there is a strong possibility that electromagnetic fields contribute to cancer in those living near overhead power lines. In those circumstances, I am calling on the Minister to comment conclusively on the health aspects. If I were her, I would not want on my conscience any negative effects of a newly proposed giant, high-voltage power line between Lackenby and Shipton via Picton through the Vale of York. I hope that an element of doubt will be raised this evening sufficient to delay the construction of that line until the health aspects have been fully explored.

House of Commons research paper 94/119 of 24 November 1994, entitled "Overhead Power Lines and Health", takes up the suggestion that exposure to electromagnetic fields near overhead power lines may increase the risk of contracting cancer. It examines scientific evidence for such a link. It summarises the relevant exposure restrictions recommended by the National Radiological Protection Board, based on established health effects arising from exposure to electromagnetic fields and radiation.

Electricity and magnetism are different aspects of the same physical phenomenon. They are natural processes that are seen in thunderstorms. The earth has a steady, static electric field arising from electrically charged atoms and molecules in the atmosphere. The strength of this electrical field near the ground is about 120 volts per metre. That is a measure of the force that would be exerted on an electrically charged particle placed in the region of space permeated by the field. Electrical currents below the earth's crust give rise to a magnetic field. The direction of that field is determined by the force that it exerts on a compass needle.

Teslas give magnetic flux density—the common measure of strength of magnetic fields. The House of Commons research paper gives the power frequency magnetic flux densities at various distances from various household appliances. At 3 cm from a hair dryer, the magnetic flux density in microteslas falls within the range of six to 2,000 microteslas. At 30 cm from a hair dryer, it falls between 0.01 or less and 7 microteslas. At 3 cm from a gentleman's electric shaver, it falls between 15 and 15,000 microteslas. At 1 cm from an electric overblanket, it falls between 2 and 3 microteslas.

On 10 June 1997, the Minister replied to a written question on potential health risks posed by mobile phone usage and the use of electric blankets. She said: "The Department obtains advice from the National Radiological Protection

Board ... on the risks to health of exposure to electromagnetic fields.” “The NRPB's advice is based on ... scientific studies ... carried out by the World Health Organisation, by the NRPB Advisory Group” and others. She said that NRPB's advice is that “there is no convincing scientific evidence that exposure to microwave radiation associated with mobile phone and electric blanket usage is harmful to ... health.”—[Official Report, 10 June 1997; Vol. 295, c. 422.]” I ask the House to contrast that decision on so-called inconclusive scientific evidence with the decision taken by the same Government—albeit a different Department, the Ministry of Agriculture, Fisheries and Food—to ban the sale of beef on the bone. Why and how did the same Government jump to ban beef on the bone with much less available evidence than we have of the dangers from electromagnetic fields? The Government are quick to act at one level and ban beef on the bone on the basis of inconclusive scientific evidence, whereas they are reluctant to act on the threat to health, particularly children's health, from exposure to electromagnetic fields near overhead power transmission lines.

Ms Sally Keeble (Northampton, North) I congratulate the hon. Lady on securing this important Adjournment debate. I also congratulate the Minister on her appointment.

Is the hon. Lady aware that there is a cluster of families in my constituency whose children have had childhood leukaemia, two of whom tragically died? Is she also aware that Professor Henshaw is coming this weekend to look at the impact of power cables that are above the ground and close to the railway lines behind their homes, and to consider the possible role that electromagnetic fields from those power cables may have played in causing the children's illness?

Miss McIntosh I am indeed. I am grateful to the hon. Lady for raising that issue. The House and the Minister will have cause to be grateful to Professor Henshaw for his studies. I hope that some good news follows from his visit to the hon. Lady's constituency.

The Government and the National Grid will argue that the proposed line through the Vale of York and elsewhere in North Yorkshire does not pass through centres of population. That is not strictly correct. Certain stages near the start of the line go through residential centres. Even in the Vale of York, the lines pass within a mile of a village or the outskirts of a town.

I believe that the Government need to develop a systematic approach to hazards whose effects are not precisely known and will become clear only over time. Although the scientific evidence may not be conclusive, it is sufficient to raise questions and concern and, in my view, to justify a delay in the construction of any further power lines until the full effects are known. The term "prudent avoidance" is often used by the United States Government in relation to possible health hazards. Although the Government will not legislate, they will advise people to avoid the dangers.

Two possible links with cancer arise from such hazards: energy effects—electromagnetic, for instance—and information effects, interfering with the body's chemical and hormonal systems. In June 1998, the United States published a report produced by the National Institute of Environmental Health Sciences, which I have with me this evening. It is important, in that it reinforces the view that power lines are a possible cause of cancer. If the Minister reads no other part of the report, I strongly urge her to read page 396, and, in particular, the conclusion that carcinogens may be caused in humans by power lines. The report states: “electric and magnetic fields such as from powerlines are a possible human carcinogen.” That statement is accompanied by a 500-page report, which is widely available on the internet. Distinguished scientists from Sweden, France and Italy participated.

The report raises the question of planning in relation to houses near power lines, and it is bound to have an impact internationally. Notably, and regrettably, no United Kingdom expert participated in the study that produced it. Is the Minister aware of that study, and of its wide health implications?

Research based at the university of Bristol under Denis Henshaw, professor of physics at the university, is concentrating on trying to find a causal mechanism to explain the acknowledged increase in the incidence of leukaemia under high-voltage power lines. Professor Henshaw is now aware of five separate mechanisms through which the electric field from power lines interacts with airborne pollutants in a way that leads to increased exposure near power lines. Childhood leukaemia is known to be associated with airborne traffic pollution, and the Bristol university hypothesis is based on increased exposure, under power lines, to an agent that is already firmly linked to childhood leukaemia.

The research has progressed as far as demonstrating increased exposure to an agent—traffic pollution—that is known to be linked to childhood leukaemia; but the general concern at Bristol university about the health effects of living under power lines goes well beyond the childhood leukaemia risk. I wonder whether the Minister is aware of the work conducted by Professor Henshaw and his team.

Another question is how far housing developments should be from a 400,000-volt power line. Given the existence of continuous and increasing exposure to environmental pollutants, 20 m is far too close. Epidemiology demonstrates that the preferred distance is 100 m. However, an unpublished report by the United States National Council on Radiological Protection in 1990 made a recommendation stating that being 150 m from overhead power lines was potentially dangerous. Does the Minister agree with that analysis?

Although the power lines that are to be built through the Vale of York from Lackenby to Shipton via Picton will not go through a large centre of population, they will nevertheless pass by such centres, and over many hamlets and large farm dwellings. Does the Minister, as a Public Health Minister, really want on her conscience the remotest possibility of the formation of clusters of cancer, such as leukaemia, which could be related to the new giant transmission line that the Government have allowed?

I invite the Minister to consider the weight of the evidence, to operate the policy of "prudent avoidance" that exists in Sweden and part of the United States, and to delay the construction of any further power lines until more is known about their health effects and potential risks. Finally, may I ask whether she will agree to a moratorium on the building of any more power lines at this time?

The Minister for Public Health (Ms Tessa Jowell) I join my hon. Friend the Member for Northampton, North (Ms Keeble) in congratulating the hon. Member for Vale of York (Miss McIntosh) on securing a debate on an issue that is extremely important to her constituents, and in regard to public health more generally.

8.25 pm

Let me give some of the background. The decision to grant consent for the building of the North Yorkshire lines was made in March this year, following public inquiries in 1992 and 1995. The then Secretary of State for Trade and Industry concluded: "in the absence of any material change in the evidence of any harmful effect from electric and magnetic fields emitted by power supply equipment, possible health effects provide insufficient grounds to refuse consent to the development." The issue applies not only to the Vale of York, but to any part of the country where people are concerned about power lines.

We are exposed to electromagnetic fields every day in many different ways, at home and at work. Kitchen appliances, computer screens in offices, security systems in shops and airports and the networks of power transmission lines and radio and television stations all emit those fields. Industry, transport and defence networks, and hospitals depend on electrical equipment emitting EMF in one form or another. It must be recognised that EMF can never be completely avoided. Electromagnetic fields also occur naturally. The earth produces natural fields: magnetic fields at the earth's surface are produced by electric currents flowing deep within the earth's core. Electric and magnetic fields are also produced in the atmosphere. The strength of those fields changes with weather conditions; that excludes the massive

effects of lightning strikes. Electrostatic fields are not uncommon, and can be encountered from charged objects in the home and at work.

During the 20th century, environmental exposure to man-made EMF has increased steadily owing to the demand for the provision and consumption of electricity, advances in technology and changes in social behaviour. In the 1960s and 1970s, the main concerns involving power lines were to do with their aesthetic impact, their interference with radio or television reception and problems with noise and perception.

In 1979, concern about the alleged link between cancer and public exposure to magnetic fields arose because of an American study of the incidence of childhood cancer in Denver. That study, and the public and media interest that it created, stimulated much of the scientific research that followed. The hon. Lady has outlined the range of conclusions that that research has produced.

Since then, many human health studies have been published around the world. Some of them have found an increased incidence of illness in people living close to power lines, but other studies have not. However, it should be noted that the risk, where it has been quantified, is usually small.

A great deal of attention, usually by the media, may be given to a study that suggests a health risk, despite the large number of other studies that do not suggest such a risk. In considering important public health issues, it is important that the balance of risk is made clear.

Currents produced in the body from electromagnetic fields near power lines are weaker than natural currents in the body, such as those produced by the brain and heart, so some scientists argue that it is impossible for EMF to have any important effects. Other scientists argue that, just as a trained ear can pick up a familiar voice or cry in a crowd, so a cell in one's body may respond to induced current as a signal that is lower in intensity yet detectable even through the background noise of the body's natural currents.

Laboratory studies, often using high-intensity electromagnetic fields—higher than those to which we are normally exposed—have shown that some biological effects can be caused by exposure to EMF. However, biological effects do not necessarily translate into health effects—an important distinction. In most cases, it is not clear how EMF produces those demonstrated biological effects; in particular, no mechanism has been established for possible carcinogenic effects.

Some biological effects are well known. Strong electric fields, such as those beneath large transmission lines, can cause hair on the exposed head or arms to vibrate slightly. That is felt by some people as a tingling sensation. EMF from transmission lines can also, in some circumstances, cause nuisance shocks from voltages created by EMF on objects or metal structures, such as fences.

Miss McIntosh I have some difficulties with the Minister's arguments, for reasons that I hope that she will understand. I believe that any death caused by living too close to a power line carrying high-voltage electricity is one death too many. Does her Department have a formula, such as the one used by the Department of the Environment, Transport and the Regions to establish how many deaths there have to be before a roundabout is built? Why is it more acceptable for a pylon to pass within 20 m or 100 m of a dwelling that houses 10 people than for a pylon to pass close to a housing development?

Ms Jowell Risk assessment is an extremely important way in which to make judgments about difficult and contentious public health issues. It is also an important and vivid way in which to convey information about risk to the public. However, it is a developing science and, although we can use calculated risk assessment to demonstrate the harm that

some actions may cause, we cannot yet use it with scientific certainty as the sole guide in making decisions that may also, for example, involve planning considerations.

Last year, the hon. Lady took part in a debate about the siting of electric pylons in her constituency; the issues that she raised were primarily environmental rather than health related. Of course, our overriding concern is to protect the public's health and to prevent death, but the means of conveying risk levels is difficult. I do not believe that the methodology is sufficiently developed to be used as the sole basis for making such decisions, which is why we rely so heavily on the expert advice of scientists who are qualified in this field.

Before I set out some of the more detailed scientific background that informs Government policy, I shall say something about the guidelines on exposure restriction. At relatively high EMF intensities, there are short-term immediate health effects—including subtle effects on the nervous system—against which people need to be protected. For some types of EMF, such as microwaves, the main effect is the heating up of tissues in the body.

Those well-established effects have been thoroughly studied and documented for many years, and guidelines have been published on the exposure limits that may prevent such effects. Although the restrictions need to be considered only in industrial premises using high-intensity EMF, it is also important that people are given proper guidance about protection in their homes.

In the United Kingdom, guidance on the levels of exposure restriction is obtained from the National Radiological Protection Board, an independent body that was set up under statute to provide radiological advice. Industry and planners currently follow those guidelines to protect workers and members of the public. Discussions are under way to harmonise guidelines throughout Europe based on the recommendations of the International Commission on Non-Ionizing Radiation Protection, an organisation comprising individuals from many countries with expertise in the effects of EMF.

Both those bodies, along with the World Health Organisation, have looked long and hard into the scientific data on which they will base their guidelines. All have agreed that the available data on potential long-term effects, such as cancer, are insufficient to provide a basis for setting exposure conditions.

In 1992, the overall position was summed up in a review of the published literature by the NRPB's advisory group on non-ionising radiation. The advisory group concluded that there was no firm evidence of a carcinogenic hazard from exposure that could be associated with residence near major sources of electricity supply, the use of electrical appliances or work in the electrical, electronic or telecommunications industries. The independent advisory Committee on Medical Aspects of Radiation in the Environment endorsed the advisory group's report.

The advisory group's position was mirrored in the US by the National Academy of Sciences, which undertook a similar review in 1997. A more recent epidemiological study of childhood cancer by the US National Cancer Institute produced results that, using the authors' own words, can be summarised as "reassuring rather than alarming".

Very recently, the National Institute of Environmental Health Sciences working group voted, by majority, that EMF should be treated as a "possible human carcinogen", a definition that appears to be based on a recognised category laid down by the International Agency for Research on Cancer. The proposal is at public consultation stage, and a final report is due to go to Congress before the end of 1998.

Despite the reassurances of some of the reviews and statements, there clearly remains widespread concern. Moreover, the positive association from a few studies suggests that there is good reason to continue to investigate the issue both experimentally and epidemiologically. Indeed, all the bodies—and we ourselves—agree that more work needs to be done to shed light on the issue and create the greater basis of certainty that we all want.

Miss McIntosh There was inconclusive evidence for the ban on beef on the bone, and many would say that the weight of evidence was in favour of continuing to sell it. I do not see the logic of banning beef on the bone, but allowing what is clearly a health risk to continue. There could well be evidence of that risk in the Minister's constituency.

Ms Jowell That is an important point. Risk assessment—knowing what the odds are—takes us part of the way, but does not provide us with the definitive basis for action. Beef on the bone was banned because of the judgment that there could be a risk of a further opportunity for BSE, in the form of new variant CJD, to be transmitted into the human food chain, not only through eating beef, but through eating stocks, broths, soups and other preparations made from bones that might have been contaminated.

We considered carefully the Spongiform Encephalopathy Advisory Committee's advice on that and on other aspects of BSE, and our efforts to understand more about new variant CJD—a devastating disease about which we know so little—and, from a public health point of view, we considered it essential to close every possible window of opportunity for further contamination or further infection of humans with the properties that translate into new variant CJD.

I reiterate the clear view that there is a need for further research to allay public concern. The positive association from a few studies suggests the need for further investigation. A number of human health studies have been carried out, especially in Europe and North America, and more are under way. Most of the emphasis has been on cancer. A few of the studies suggest that exposure to low levels of EMF may cause some effect, but those findings have tended to be weak and inconsistent, and other studies suggest no increased risk of the disease. Until now, most scientists and clinicians have agreed that the health effects of low-level EMF are likely to be very small, if they exist at all.

Experiments with healthy volunteers clearly show that short-term exposure at the levels experienced in the environment or in the home do not cause any clinical or pathological effects. Some studies report effects, but they tend to be inconsistent between studies. Many animal and cellular studies have failed to show any significant effects of exposure. Reported effects tend to be small and experiments must be performed with great care for any effect to be detected.

A great deal of effort is being directed towards investigating the effects of magnetic fields on cancer. It seems that magnetic fields alone cannot cause cancer, although some laboratory studies suggest that they speed up the development of existing cancers.

In 1996, the international EMF project was initiated by the World Health Organisation. The project will assess health and environmental effects of exposure to time-varying electromagnetic fields. The project is being carried out in collaboration with national and international agencies, organisations and research institutions. The Department of Health is contributing to the funding of this large undertaking, as is the Health and Safety Executive.

The NRPB, which is highly regarded throughout the world for its expertise in the field, is an official collaborating institution with the WHO EMF project. Many international organisations are involved and a series of international seminars is being held where leading scientists present status reports on dosimetry, in vitro, in vivo and human studies. The project will publish environmental health criteria monographs of the scientific literature towards the end of the five-year programme.

The Department of Health also supports the United Kingdom childhood cancer study, a key study due to report next year. The study was set up in 1992 and is the largest of its type. It is investigating cases of childhood cancer for which the causes are still unknown. EMF is one of a number of possible causes included in the study. The Department also supports another type of epidemiological study of childhood cancer and some biological laboratory work. Results will be published in the scientific press when the studies are complete.

Researchers at Oxford university have been investigating the effects of EMF on free radicals in the body. Others, such as Professor Henshaw at Bristol university, have proposed the idea that electric fields attract very small particles such as bacteria, thereby increasing the likelihood of disease in their vicinity.

I hope that that makes it clear that we are faced with scientific data that produce a range of conclusions. The way in which we act on those conclusions is to subject the analysis to scrutiny by the experts on the NRPB. The hon. Lady raised several important points about the continuing uncertainty. The development of risk assessment, the application of best available evidence and the continuing search for greater certainty will guide what we do. We will ensure that the conclusions are published and that the process by which our decisions are reached is transparent. Ultimately, our overriding concern will be the protection of public health and safety.

Question put and agreed to.

Adjourned accordingly at twelve minutes to Nine o'clock.

Slide 1



Trim, Co. Meath
Ireland
10th February 2014



**Scientific basis of the health effects of electric
and magnetic fields associated with the
electricity supply**

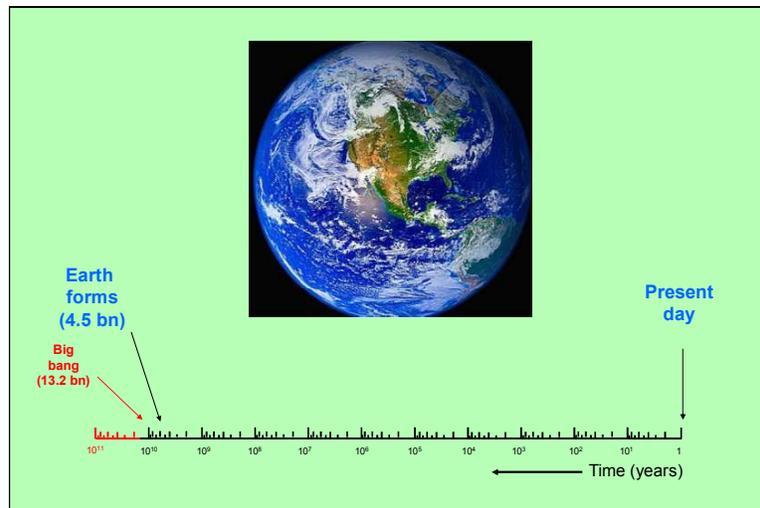
Denis L Henshaw

University of Bristol
and
Children with Cancer UK



First I will demonstrate a magnetic field and an electric field. They are quite distinct. At power frequencies, the two fields are essentially independent and can be treated separately.

Slide 2



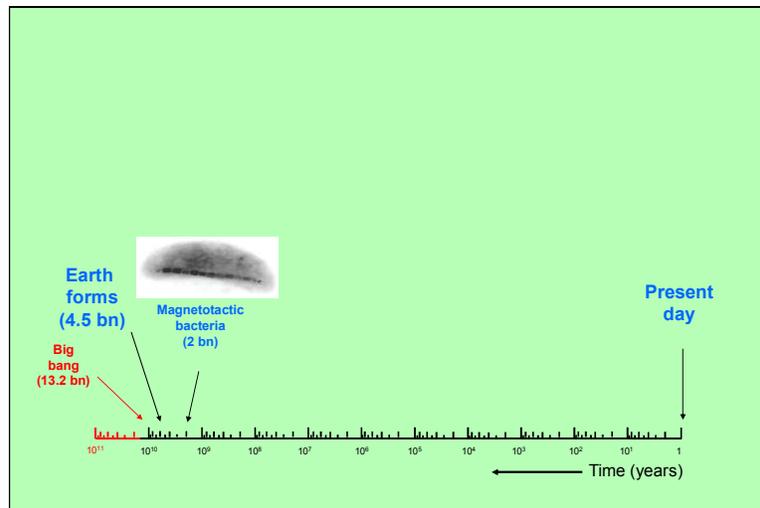
When the Earth was formed 4.5 billion years ago magnetic fields were already present, and had been since the Big Bang some 9 billion years earlier.

2 billion years ago aquatic magnetotactic bacteria evolved which contain a chain of magnetite particles enabling them to swim along the Earth's magnetic field lines to find food.

Over 90 million years ago the avian magnetic compass developed, enabling pigeons to detect magnetic field changes around 0.02 μT , 20 nT, or even lower.

Some 6 million years ago, man evolved, some of whom appear sensitive to solar storm fluctuations in the geomagnetic field of around 0.1 μT or 100 nT.

Slide 3



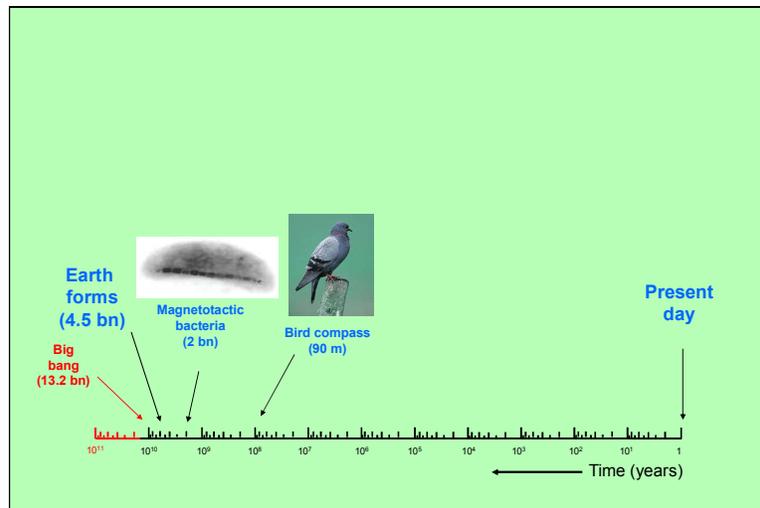
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Slide 4



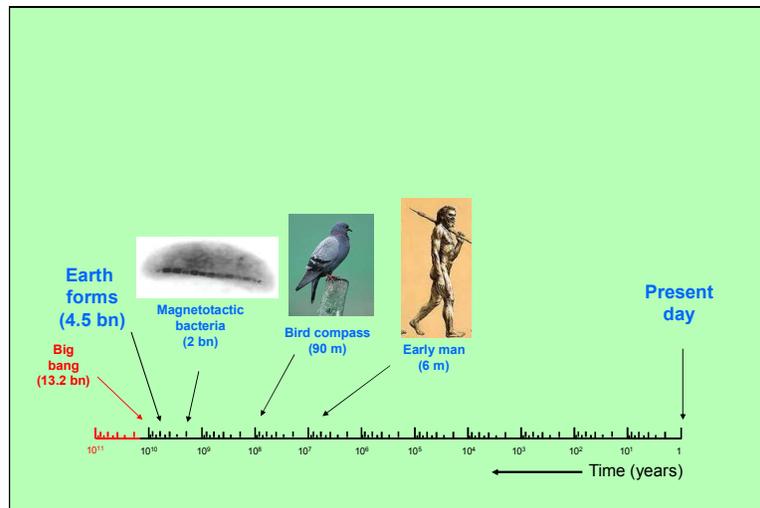
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Slide 5



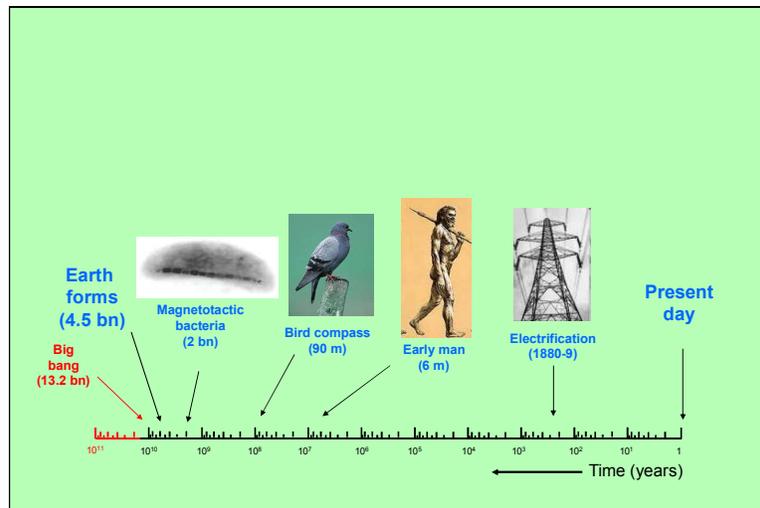
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Slide 6



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Some 6 million years ago, man evolved, some of whom appear sensitive to solar storm fluctuations in the geomagnetic field of around 0.1 μT or 100 nT.

So, by the time the Dublin electric light company was established in 1880 and, soon after, an experimental public light was erected outside the offices of the Freeman's Journal in Prince's St. Dublin, it was already the case that wide sections of the animal kingdom had evolved to detect and exploit magnetic fields at levels below those associated with this new invention, and with hindsight, a hint that there might be adverse health effects in humans.

Notes only:

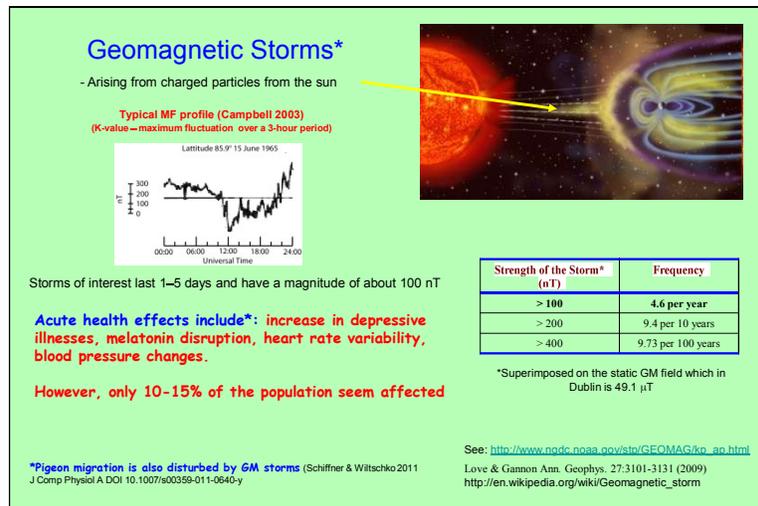
The species whose magnetic compass has been analyzed so far are not at all closely related. Chickens belong to an ancient line of birds, the Galloanseres, that separated from the remaining modern birds, the Neoaves, more than 90 million years ago in the beginning of the Late Cretaceous Finding the same type of

magnetic compass in species of all three groups suggests that this compass mechanism may have already been present in their common ancestor.

From: **Turn On The Lights** Electrification Comes To Rural Ireland:

In 1880, Thomas Edison invented the electric filament lamp in the US. In the same year, the Dublin Electric Light Company was established and, soon after, an experimental public light was erected outside the offices of the Freeman's Journal in Prince's St. Dublin, followed by seventeen public lights in the vicinity of Kildare St., Dawson St. and St. Stephen's Green. In 1889, Carlow became the first provincial town in Ireland to get public electric lighting, supplied from a generator in a flour mill some four miles away.

Slide 7



So, start by taking as quick look at Geomagnetic storms

Superimposed on the Earth's static magnetic field of 49.1 μ T in Dublin, are small fluctuations caused by storms of charged particles emitted by the Sun

They are categorised by their K-value, their maximum variation over a three hour period.

The storms of interest are those around 100 nT, there being about 4.6 such 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

Much of this research was carried out as part of the US and Russian Space Programme

Slide 8

Health effects of Geomagnetic storms

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*Reviews of studies

Here is a short list of some of the studies of health effects resulting from geomagnetic storms, the first two are reviews

Power frequency electric & magnetic fields
- especially magnetic fields, MFs[†]



Appliances:
can be tens
of μT close to

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

Under powerlines MFs can be several μT or evens tens of μT

Doubling of Childhood Leukaemia risk associated with average 0.3/0.4 μT *

Average MF home levels 0.05 μT

*and 30% increase in risk above 0.2 μT

*Robust association reiterated in 2014 EU SCENIHR Report

[†]Magnetic fields are an IARC Class 2B Possible Carcinogen

So, let's now look at power frequency magnetic fields. In 2002 these were classified by The International Agency for Research on Cancer (IARC) as a Class 2B Possible carcinogen – similar to coffee: drinking 3-8 cups of coffee per day in pregnancy can lead to a 2-3 fold increase in childhood leukaemia risk in offspring.

The average exposure to power frequency magnetic fields in the home is only 0.05 microtesla (μT) or 50 nanotesla (nT). However, close to certain appliances, levels can be tens of μT . Under powerlines MFs can be several μT or evens tens of μT

Crucially a doubling of childhood Leukaemia risk is associated with average exposure of 0.3/0.4 μT . Further analyses of international epidemiological studies indicate a 30% increase in childhood leukaemia risk associated with average magnetic field exposures above 0.2 μT (Zhao et al 2013. Leukaemia Research In press – online early).

What are the adverse health effects linked to power frequency electric & magnetic fields?

- Childhood leukaemia
- Adult leukaemia
- Adult brain tumours
- ALS (motor neurone disease)
- Miscarriage & adverse birth outcomes*
- Depression & depressive symptoms
- Alzheimer's disease
- Breast cancer

*Including newly emerging finds: De Vocht et al 2014 Bioelectromagnetics, in press

Slide 11

Review bodies' assessments of MF association of various diseases.
 - IARC has classified Power Frequency MFs as Class 2B – 'possible carcinogen'.

Disease	NIEHS 1999 ¹	IARC ² 2002	California* 2002	EU: SCENIHR 2014 ³	EMF & Health 2011 ⁴
1. Childhood Leukaemia	Yes	Yes	Yes	Yes	Yes
2. Adult Leukaemia ⁵	Yes		Yes		Yes
3. Adult brain cancer ⁵			Yes		Yes
4. Miscarriage			Yes		Yes
5. ALS ⁶			Yes		Yes
6. Alzheimer's disease				Yes ⁷	Yes

¹US National Institute of Environmental Sciences
²International Agency for Research on Cancer
³EU: Scientific Committee on Emerging and Newly Identified Health Risks: Possible effects of Electromagnetic Fields (EMF) on Human Health.
⁴EU: EMF & Health, Brussels Nov 2011
⁵Motor neurone disease
⁶Motor neurone disease
⁷Studies more recently published

⁵Aggregated data is highly significant:
 O'Carroll and Henshaw 2008. Risk Analysis 28:225-234.
 Kheifets et al. 2008. JOEM 50:677-688.

*<http://www.ehpb.org/emf/RiskEvaluation/riskeval.html>

Here is what various review bodies have said about Magnetic Field and adverse health effects

IARC 2002 must have had a bad day because their own listing of studies shows strong evidence of association (See O'Carroll & Henshaw 2008 and also Kheifets et al 2008). In fact the MF link with adult leukaemia is, if anything, even stronger than the link with childhood leukaemia

Representative results from 33 independent adult leukemia studies tabled by IARC yielded 23.5 positives ($p \approx 0.01$) and 9 significant-positives ($p < 10^{-7}$). From 43 representative results from CDHS, there were 32 positive ($p < 0.001$) and 14 significant-positives ($p < 10^{-12}$). There were no significant-negative results in either list. Results for adult brain cancer gave a similar, but less clear message.

Features of the above Reports

- Not peer-reviewed (although the California report* used a structured assessment procedure)
- Dominated by **epidemiology** and not underlying science
- Cite at most only a few 100 papers against possibly over 100,000 available
- Do not discuss (out of remit):
 - Magnetoreception in microorganisms and fungi
 - Magnetoreception in plants
 - Animal magnetoreception and navigation
 - EMF effects on pain threshold in animals
 - Health effects of geomagnetic storms
 - Use of EMF in health treatment including cancer

But it is in these areas that significant advances in understanding how EMFs interact with biology have been made

*<http://www.ehib.org/emf/RiskEvaluation/riskeval.html>

Slide 13

Review bodies' assessments of MF association of various diseases.
 - IARC has classified Power Frequency MFs as Class 2B – 'possible carcinogen'.

Disease	NIEHS 1999 ¹	IARC ² 2002	California* 2002	EU: SCENIHR 2014 ³	EMF & Health 2011 ⁴
1. Childhood Leukaemia	Yes	Yes	Yes	Yes	Yes
2. Adult Leukaemia ⁵	Yes	- (why?)	Yes		Yes
3. Adult brain cancer ⁵		- (why?)	Yes		Yes
4. Miscarriage			Yes		Yes
5. ALS ⁶			Yes		Yes
6. Alzheimer's disease				Yes ⁷	Yes

¹US National Institute of Environmental Sciences
²International Agency for Research on Cancer
³EU: Scientific Committee on Emerging and Newly Identified Health Risks: Possible effects of Electromagnetic Fields (EMF) on Human Health.
⁴EU: EMF & Health, Brussels Nov 2011
⁵Motor neurone disease
⁶Motor neurone disease
⁷Studies more recently published

⁵Aggregated data is highly significant:
 O'Carroll and Henshaw 2008. Risk Analysis 28:225-234.
 Kheifets et al. 2008. JOEM 50:677-688.

*<http://www.ehpb.org/emf/RiskEvaluation/riskeval.html>

Here is what various review bodies have said about Magnetic Field and adverse health effects

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IARC & California assessment of epidemiological studies Why the difference for adult leukaemia & brain cancer?

How epidemiology works

- The epidemiological studies look at cancer rates near MF sources and compare these with rates well away from MF sources
- We obtain risk ratio, RR:
 - If cancer rates are the same near and away from MF sources RR = 1,
 - if cancer rates are doubled near MF sources, RR = 2

We also look at the probability of the finding being just due to chance (being just a fluke)
– This is known as the “p-value”

If the probability of the finding being due to chance is better than **1 in 20 (p<0.05)** we say the finding is **statistically significant**.

Sometimes p-values, especially for many studies **considered together** can be far more significant

e.g. p<0.001 or 1 in 1000 probability of the finding being just chance

Nobel Prize in Physics 2013



François Englert
Université Libre de Bruxelles



Peter W. Higgs
University of Edinburgh

Following the discovery at CERN, Geneva of the new particle known as the Higgs boson

Confirmed (established) when the probability of the finding being just due to chance was less than

1 in 10 million

or p-value $< 10^{-7}$ or 99.99999% “proof”

The Nobel Prize in Physics 2013 was awarded jointly to François Englert and Peter W. Higgs “for the theoretical discovery of a mechanism that contributes to our understanding of the origin of mass of subatomic particles, and which recently was confirmed through the discovery of the predicted fundamental particle, by the ATLAS and CMS experiments at CERN’s Large Hadron Collider”

IARC & California assessment of epidemiological studies
O'Carroll and Henshaw

Adult Leukaemia: (Risk Analysis 2008; 28:225-234)

IARC listed 33 independent studies: Claimed "No association with MFs"
- but offered no evidence for this conclusion

We analysed the 33 studies taken together: Evidence of association with MFs

- We calculated the p-value for this association.

1 in 10 million
(the probability that the result occurred simply by chance)

or p-value $<10^{-7}$ → 99.99999%
By any definition: proof/established that the association is not a fluke

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

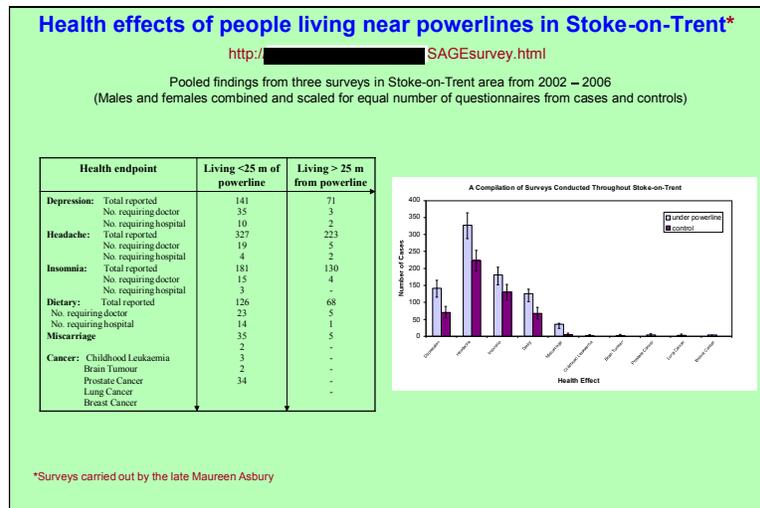
By any accepted definition, there is an established association between magnetic fields from the electricity supply and adult leukaemia and brain cancer

Bioinitiative 2012:

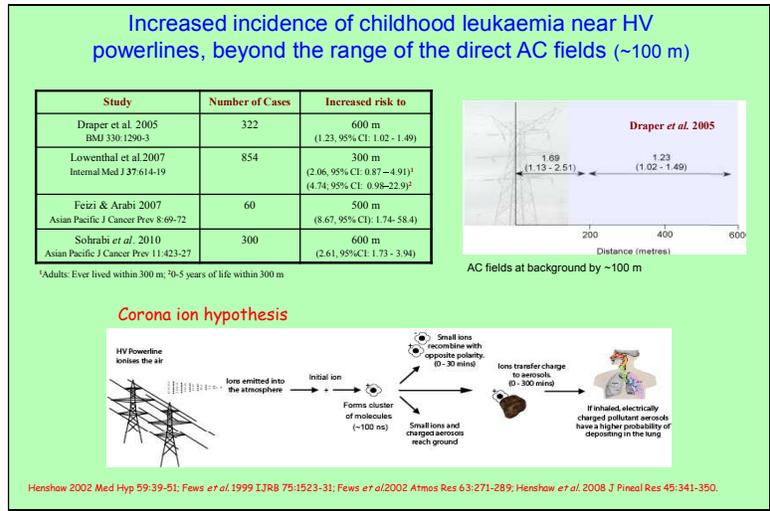
- a biologically-based EMF Report

<http://www.bioinitiative.org>

- Highly authoritative – 12 authors representing world-class leading EMF scientists including **three former Presidents of the International Bioelectromagnetics Society**
- Concentrates on the underlying biology of ELF and RF EMF
- Special chapters on **melatonin disruption, childhood cancers, breast cancer & Alzheimer's disease**
- Cites approximately 1800 peer-reviewed studies
- **Strongly recommends precaution against EMF exposure at levels well below current International guidelines.**



These surveys were carried out in three estates with very similar private housing, away from major roads or sources of industrial pollution. While this is not a professional survey, the findings closely mirror those published in the peer-reviewed literature.

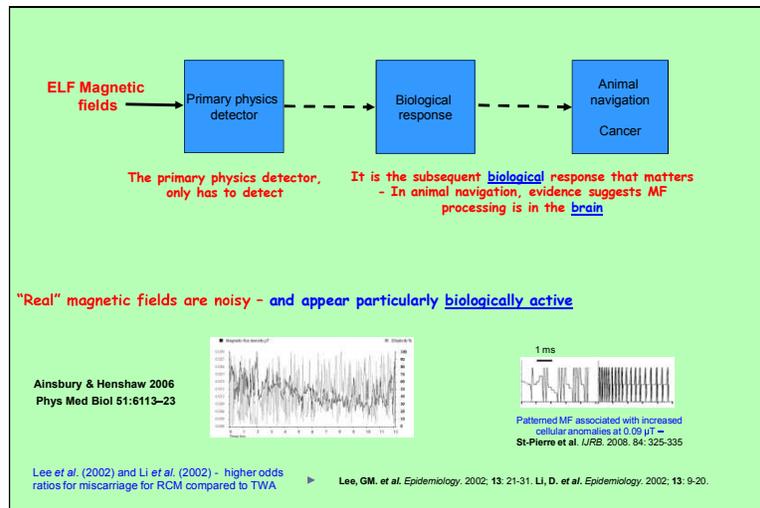


The literature includes four studies showing increased leukaemia risk up to 600 metres from powerlines which is well beyond the range of the AC fields, although well within range of corona ion emission. The findings could be explained by two possible models: that corona ions attach to particles of air pollution making them more likely to be retained in the lung when inhaled, and that corona ion disturbance of the natural electric field of the Earth results in melatonin and circadian rhythm disruption.

EMF effects on cattle

- Rodriguez M, Pettitlerc D, Burchard JF, Nguyen DH, Block E. 2004. Blood Melatonin and Prolactin Concentrations in Dairy Cows Exposed to 60 Hz Electric and Magnetic Fields During 8 h Photoperiods. *Bioelectromagnetics* 25:508-15.
- Rodriguez M, Pettitlerc D, Burchard JF, Nguyen DH, Block E, Downey BR. 2003. Responses of the estrous cycle in dairy cows exposed to electric and magnetic fields (60 Hz) during 8-h photoperiods. *Animal Reproduction Science* 77:11–20.
- Burchard JF, Nguyen DH, Richard L, Block E. 1996. Biological Effects of Electric and Magnetic Fields on Productivity of Dairy Cows. *Journal of Dairy Science* 79:1549-1554.
- Burchard JF, Nguyen DH, Block E. 1999. Macro- and Trace Element Concentrations in Blood Plasma and Cerebrospinal Fluid of Dairy Cows Exposed to Electric and Magnetic Fields. *Bioelectromagnetics* 20:358–364.
- Burchard, J. F., Monardes, H. and Nguyen, D. H., 2003. Effect of 10 kV, 30 μ T, 60 Hz electric and magnetic fields on milk production and feed intake in nonpregnant dairy cattle. *Bioelectromagnetics*, 24, 557-563.
- Burchard, J. F., Nguyen, D. H. and Rodriguez, M., 2006. Plasma concentrations of thyroxine in dairy cows exposed to 60 Hz electric and magnetic fields. *Bioelectromagnetics* 27:553-559.
- Burchard JF, Nguyen DH and Monardes Hg, 2007. Exposure of pregnant dairy heifer to magnetic fields at 60 Hz and 30 μ T. *Bioelectromagnetics* 28:471-476.
- Lee, JR JM, Stormshak F, Thompson JM, Thinesen P, Painter LJ, Olenchek EG, Hess DL, Forbes R, Foster DL, 1993. Melatonin Secretion and Puberty in Female Lambs Exposed to Environmental Electric and Magnetic Fields. *Biology of Reproduction* 49:857-864 – *total melatonin unaltered, but severe disruption of circadian rhythms*
- Lee, JR JM, Stormshak F, Thompson JM, Hess DL, Foster DL. 1995. Melatonin and Puberty in Female Lambs Exposed to EMF: A Replicate Study. *Bioelectromagnetics* 16:119-123.

Slide 21

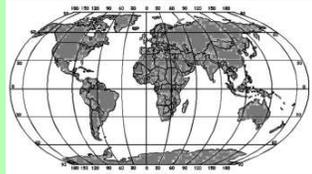


There is a key difference between the initial detector which senses magnetic fields, and the subsequent biological response. For example, the ear senses music, but the brain decides whether it likes it or not.

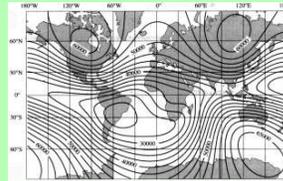
Some underlying biology.....

Navigation across the Earth

- requires two measurements

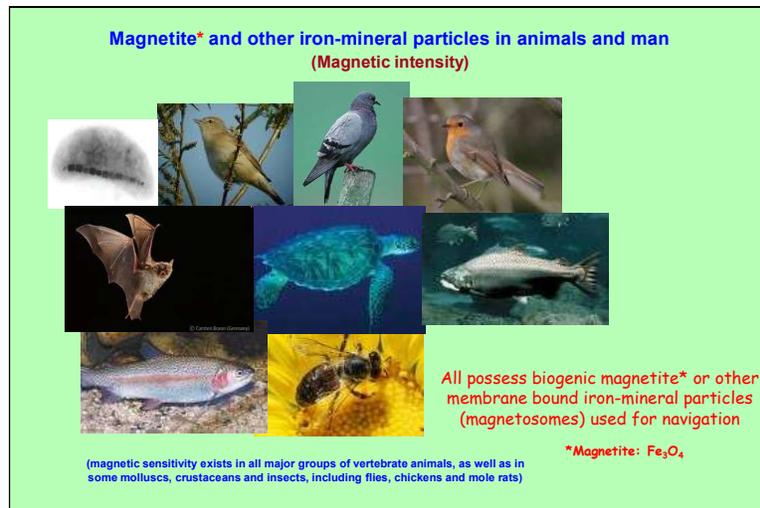


Humans use latitude & longitude



Many animals use magnetic intensity and compass direction of the Earth's magnetic field

Slide 24



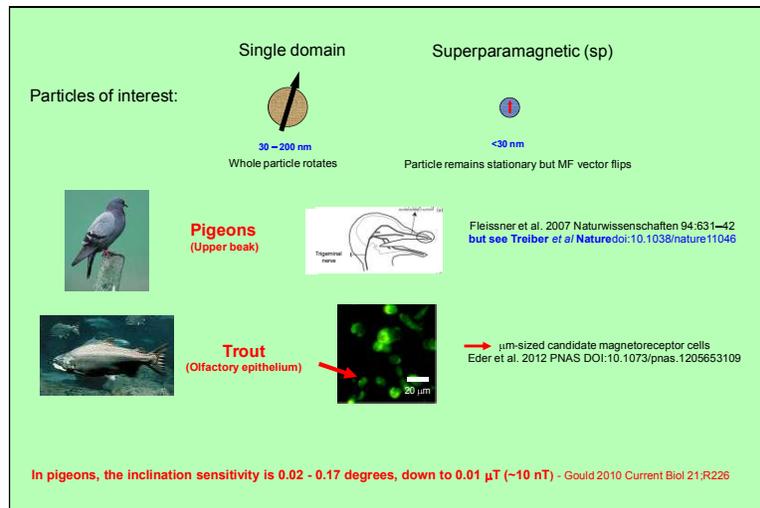
Magnetic sensitivity is widespread throughout the animal kingdom, and these are some of the animals which possess biogenic magnetite or other iron-mineral particles used for navigation

Notes:

Jogler C, Schüler D. 2009. Genomics, Genetics, and Cell Biology of Magnetosome Formation. Annual. Review of Microbiology 63:501–21.

Lohmann: magnetic sensitivity is phylogenetically widespread; it exists in all major groups of vertebrate animals, as well as in some molluscs, crustaceans and insects. The list includes groups such as flies, chickens and mole rats, none of which migrate.

Slide 25



Single domain permanent magnets, particles >50 nm where the whole particle physically rotates in an MF

And

Superparamagnetic particles which remains stationary but the MF vector quantum flips

Fleissner et al 2007 Goethe-Universität, Frankfurt

Treiber et al 2012 1Institute of Molecular Pathology, Dr Bohr-Gasse, 1030 Vienna, Austria

Eder & Michael Winklhofer Ludwig-Maximilians-University Munich

Notes:

Heyers D, Zapka M, Hoffmeister M, Wild JM, Mouritsen H. 2010. Magnetic field changes activate the trigeminal brainstem complex in a migratory bird. Proceedings of the National Academy of Sciences USA 107:9394-9399.

BUT: Zapka M, Heyers D, Hein CM, Engels S, Schneider N-L, Hans J, Weiler S, Dreyer D, Kishkinev D, Wild JM, Mouritsen H. 2009. Visual but not trigeminal mediation of magnetic compass information in a migratory bird. Nature 461:1274-1278. doi:10.1038/nature08528

Falkenberg G, Fleissner G, Schuchardt K, Kuehbacher M, Thalau P, et al. (2010) Avian Magnetoreception: Elaborate iron mineral containing dendrites in the upper

beak seem to be a common feature of birds. PLoS ONE 5(2): e9231. chickens, homing pigeons, European robin, Garden Warbler.

Magnetic particles in human brain and ferritin
(Kirschvink et al. (1992) PNAS 89:7683-7 and Allen et al. 2000 Biochimica et Biophysica Acta 1500;186-196)

1. Human brain: Kirschvink et al. characterised magnetite biomineralisation in adult human brain:

- Sizes **10 – 70 nm** & **90 – 200 nm**, some **600 nm**. 5 million single-domain crystals/g for most brain tissues, >100 million crystals/g for pia and dura – the layers near the skull.
- Particles in clumps of between **50** and **100** particles; **U/kT values between 20 and 150.**
- **The larger particles could respond to a 50 Hz field at 0.4 μ T - putting mechanical stress on neighbouring cells**

2. Ferritin:

- has a natural ferrihydrite nano-particle, ~8 nm, superparamagnetic, SP at room temperature.
- 1 – 200 mT fields in their vicinity; ~1 mT at 50 nm away
- SP particle would effectively **"amplify"** a 0.4 μ T 50 Hz field by induced magnetisation - [Binhi 2008 IJRB 84:569-579](#)

Superparamagnetic (SP)
 <30 nm
Particle remains stationary but MF vector flips

Notes:

Binhi 2008 IJRB 84:569-579

In horse spleen ferritin, up to 30% of the core exhibits magnetite/maghemite structure (Brem et al 2006)

See also, magnetite in the brain of Alzheimer's patients and human heart, liver and spleen (Dobson 2001, Brem et al. 2006, Collingwood et al. 2008), (Grass-Schultheiss et al. 1997).

Vanderstraeten J. Gillis P. 2010. Theoretical Evaluation of Magnetoreception of Power-Frequency Fields. Bioelectromagnetics 31:371-379

Joseph L. Kirschvink 1996. Microwave Absorption by Magnetite: A Possible Mechanism for Coupling Nonthermal Levels of Radiation to Biological Systems. Bioelectromagnetics 17:187-194 (1996)

Allen et al. 2000. Low-frequency low- ϕ eld magnetic susceptibility of ferritin and Hemosiderin Biochimica et Biophysica Acta 1500;186-196

A second mechanism of low level MF detection

(Magnetic compass)

- The process known as the Radical Pair Mechanism, RPM

- Low intensity MFs can increase the lifetime of free radical pairs*
- This leads to changes in chemical reaction products which can form the basis of a chemical magnetic compass
- The process also results in free radicals becoming more available to cause biological damage

*They do so by altering the spin states of radical pairs- increasing the rate of transition from the short-lived singlet (S) to the longer-lived triplet (T) state - details at end of talk

A full explanation of the RPM may be found in slides at the end of this talk.

Now let's look at a second mechanism of MF detection in animals
– a chemical compass in the eye based on the RPM*



*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

These species all have a light-dependent compass with evidence that it is based on the RPM. Notice that in some cases, this is in addition to magnetite. Notice also the involvement of the pineal gland in some species

From Lohmann 2010: Figure 1 | Animal magnetism. Diverse species have magnetic compasses, including (clockwise from top left) the European robin, the loggerhead sea turtle, the brown bat, the Caribbean spiny lobster and the red-spotted newt. A few, including turtles, lobsters and newts, also have magnetic maps.

Proposal by Ritz et al. 2000
(Biophys J 78:707-718)

-proposed that the MF reception in birds was mediated via the RPM on cryptochromes in the eye

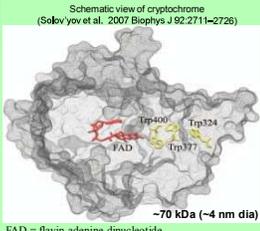


-50-90 kDa blue-light photoreceptor; flavoproteins - best known for their role in controlling circadian rhythms. High sequence-homology to DNA photolyases.

Requirements of a chemical compass:

- ✓ produces a radical pair by blue light photon absorption and electron transfer
- ✓ Undergoes increased S-T interconversion in GM field
- ✓ RPs have a lifetime ~1 μ s or longer¹
- ✓ Has an anisotropic response
- ✓ Can be anchored (in the eye)²

Ritz proposed that RF fields ~1 MHz might interfere with the MF compass



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

~70 kDa (~4 nm dia)

FAD = flavin-adenine dinucleotide
Radical pair consisting of FADH[•] and the terminal Tryptophan residue of the cryptochrome Trp-triad, RP separation is ~1.9 nm (Efremova & Hore 2008)

¹Liedvogel et al. 2007 *PLoS One* 2(10): e1106; ²Cry1a located in UV/V-cones Niessner et al. 2011 *PLoS ONE* 6(5): e20091

Ritz et al 2000 proposed that the avian compass was based on cryptochrome molecules in the eye and that as an experimental test, this might be interfered with by application of an appropriate RF field

RP lifetimes up to 20 ms – five orders of magnitude higher than 1 ms required have been observed: Liedvogel et al. 2007, Chemical magnetoreception: bird cryptochrome 1a is excited by blue light and forms long-lived radical-pairs” *PLoS One* 2(10): e1106; and

Cry1a located in UV/V-cones in robins and chickens, in ordered bands along the membrane discs (Niessner et al. 2011 *PLoS ONE* 6(5): e20091)

FAD = flavin-adenine dinucleotide

Ritz et al. 2004
Nature 429:177-180

Birds: European robins, *Erithacus rubecula*: 12 individually tested in spring migration season.

MF exposure: Local GMF 46 μ T, inclination 66° and 565 nm light (control) plus: (i) broadband 0.1–10 MHz, 0.085 μ T; (ii) single frequency 7 MHz, 0.47 μ T; all parallel, 24° or 48° to GMF vector.

Results:

- RF magnetic fields disrupt the magnetic orientation behaviour of migratory birds.
- Robins were disoriented when exposed to a vertically aligned broadband (0.1–10 MHz) or a single-frequency (7-MHz) field in addition to the geomagnetic field.
- In the 7-MHz oscillating field, effect depended on the angle between the oscillating and the geomagnetic fields.
- Birds exhibited seasonally appropriate migratory orientation with no applied RF or when the RF field was parallel to the geomagnetic field, but were disoriented when it was presented at an angle of 24° or 48° at 0.085 μ T.

Conclusion:

These results are consistent with a resonance effect on singlet-triplet transitions and suggest a magnetic compass based on a radical pair mechanism.

These findings have been replicated in robins and seen in chickens, zebra finches and American cockroaches



FAD = flavin-adenine dinucleotide

Slide 31

Effects of animal magnetic compass orientation with RF and ELF EMF exposures (GMF = geomagnetic field).

Study	MF and light exposure	Findings
Ritz et al. 2004: European robins, <i>Erithacus rubecula</i> ; 12 individually tested in spring migration season.	Local GMF 46 μ T, inclination 66° and 565 nm light (control) plus: (i) broadband (0.1–10 MHz, 0.085 μ T) (ii) single frequency 7 MHz, 0.47 μ T; all parallel, 24° or 48° to GMF vector.	Birds exhibited seasonally appropriate migratory orientation with no applied RF or when the RF field was parallel to the geomagnetic field, but were disoriented when it was presented at an angle of 24° or 48° at 0.085 μ T.
Thalau et al. 2005: As in Ritz et al. 2004 using 12 robins in spring and 16 robins in autumn.	As in Ritz et al. 2004, but applying RF at the local Larmor frequency of 1.315 MHz at 0.485 μ T, parallel and at 24° to GMF vector.	Birds exhibited seasonally appropriate migratory orientation in both spring and autumn with no applied RF or when the RF field was parallel to the geomagnetic field, but were disoriented when applied at 24° at 0.485 μ T.
Wiltshcko et al. 2007: Domestic chickens, <i>Gallus gallus</i> , 36 in total, between 12 and 22 days old.	Local GMF 55.9 μ T, inclination 62°, artificially orientated East as control, and white, 465 nm blue or 645 nm red light plus: (i) local Larmor frequency 1.566 MHz* at 0.48 and 0.048 μ T vertical (28° from GMF vector), (ii) 50% weaker and stronger: 27.9 μ T and 83.8 μ T and (iii) 25% weaker and stronger: 41.9 μ T and 69.9 μ T.	1. Chickens orientated well in control field, but in general not in the weaker and stronger fields, suggesting a functional window around the GMF. 2. Tendency to orientate well under white and blue light, but not red, but results not statistically significant. 3. Exposure to 1.566 MHz led to disorientation suggestive of an underlying radical pair mechanism.
Stapput et al. 2008: European robins, <i>Erithacus rubecula</i> ; 12-16 per test	Local GMF 46 μ T, inclination 66° and 565 nm green light or total darkness, alone (control) or plus 1.315 MHz at 0.48 μ T, 24° to GMF vector.	Normal seasonal migratory orientation under 565 nm light. In total darkness, birds orientated NW, not the migratory direction, and were not disrupted by 1.315 MHz fields, although were disrupted by anaesthesia of the upper brain. Findings suggestive of two magnetic compass systems: (i) an inclination compass based on radical pair processes allowing orientation in the migratory direction and (ii) an iron-based system that, aside from providing 'intrap' information, can affect orientation in 'fixed directions' in the absence of light, but is normally dormant when the radical-pair mechanism is operating.
Keary et al. 2009: Zebra finches, <i>Taeniopygia guttata</i> , 10 for MF orientation; 7 for visual perception	Local GMF 43 μ T, inclination 67° daylight. Local Larmor frequency 1.156 MHz at 0.47 μ T, horizontal component of GMF shifted 90° clockwise (control), RF added in same vector direction. Separately, birds were trained to orientate with respect to visual clues.	Birds exhibited migratory orientation in the 90° shifted control field, but this was disrupted when the RF field was added. Birds trained for visually guided orientation were unaffected by either the static or RF fields.

*This corresponds to the Larmor frequency for the free electron in the local GMF

Ritz et al. 2004 Nature 429:177-180, Thalau et al. 2005 Naturwissenschaften 92:86-90, Wiltshcko et al. 2007 J Exp Biol 210:2300-2310, Stapput et al. 2008 Curr Biol 18:602-606, Keary et al. 2009

This and the next slide:

The findings of Ritz et al 2000 have now been repeated in robins and also in chickens, zebra finches and American cockroaches

The table is very busy but I just want to point out the very low level of RF fields that disturb the compass and at frequencies corresponding to the Larmor precessional frequency of the free electron

Ritz T, Thalau P, Phillips JB, Wiltshcko R, Wiltshcko W. 2004. Resonance effects indicate a radical-pair mechanism for avian magnetic compass. Nature 429:177-180.

Thalau P, Ritz T, Stapput K, Wiltshcko R, Wiltshcko W. 2005. Magnetic compass orientation of migratory birds in the presence of a 1.315 MHz oscillating field. Naturwissenschaften 92:86-90. (DOI 10.1007/s00114-004-0595-8)

Ritz T, Wiltshcko R, Hore PJ, Rodgers CT, Stapput K, Thalau P, Timmel CR, Wiltshcko W. 2009. Magnetic compass of birds is based on a molecule with optimal directional sensitivity. Biophysical Journal 96, 3451-3457. (doi:10. 1016/j.bpj.2008.11.072)

Stapput K, Thalau P, Wiltshcko R, Wiltshcko W. 2008. Orientation of Birds in Total Darkness. Current Biology 18:602-606. (DOI 10.1016/j.cub.2008.03.046)

Wiltshcko W, Freire R, Munro U, Ritz T, Rogers L, Thalau P, Wiltshcko R. 2007c. The magnetic compass of domestic chickens, *Gallus gallus*. The Journal of Experimental Biology 210, 2300-2310.

Keary N, Ruploh T, Voss J, Thalau P, Wiltshcko R, Wiltshcko W, Bischof H-J 2009. Oscillating magnetic field disrupts magnetic orientation in Zebra finches, *Taeniopygia guttata*. Frontiers in Zoology 2009, 6:25.

Vácha M, Půžová T, and Markéta Kvíčalová M. 2009. Radio frequency magnetic fields disrupt magnetoreception in American cockroach. The Journal of Experimental Biology 212;3473-3477.

Begall S, Cerveny J, Neef J, Vojtech O, Burda H, 2008. Magnetic alignment in grazing and resting cattle and deer. Proceedings of the National Academy of Sciences of the USA 105:3451-13455.

Burda H, Begall S, Cerveny J, Neef J, Nemecek P. 2009. Extremely low-frequency electromagnetic fields disrupt magnetic alignment of ruminants. *Proceedings of the National Academy of Sciences of the USA* 106:5708-13, 2009.

Slide 32

**Effects of animal magnetic compass orientation with RF and ELF EMF exposures (GMF = geomagnetic field).
Continued:**

Study	MF and light exposure	Findings
Vácha et al. 2009: American cockroaches: 11 individually isolated from each other.	Local GMF 42.9 μ T, inclination 64°. white light: (i) These conditions as control (ii) GM North was rotated 60° in 5 min intervals Adding vertically to both of these: (iii) 1.2 MHz, 0.044 μ T, reducing (iv) 2.4 MHz, 0.044 and 0.018 μ T (v) 7 MHz, 0.044 μ T	Cockroaches were tested for locomotive activity using double-blinded procedure. 1. Changes in activity between stable and 60° periodic field rotations, indicating functionality of basic MF sense; 2. 1.2 MHz interfered with above changes, disruption threshold between 12 – 18 nT; 3. 2.4 MHz interfered with above changes, disruption threshold between 18 – 44 nT; 4. 7 MHz produced no disruption at 44 nT.
Ritz et al. 2009: European robins, <i>Erithacus rubecula</i> : 12 individually tested in spring migration season	(i) Local GMF 46 μ T, inclination 66°. 565 nm green light, plus 8 frequencies from 0.01 to 7.0 MHz including Larmor 1.3 15 MHz*, 0.47–0.48 μ T (ii) GMF artificially doubled to 92 μ T, plus 1.315 and (matched Larmor) 2.63 MHz	1. GMF of 46 μ T: (i) GMF alone: well orientated, (ii) 0.01 and 0.03 MHz: no interference, (iii) 0.1 and 0.5 MHz: weak axial response characteristic of compass on its limit of operation, (iv) 0.658 MHz and higher: disorientation, (v) Larmor frequency of 1.315 MHz*: disoriented even at 15 nT, not affected at 5 nT. 2. Static field set artificially at 92 μ T: (i) 0.5 μ T alone: well orientated, (ii) 1.315 MHz at 150 or 48 nT orientation no longer affected, (iii) 2.63 MHz: disorientation at 15 nT.
Begall et al. 2008: Worldwide satellite observations: 8,510 Domestic cattle in 308 pastures and 2,074 Roe deer at 241 localities	The natural GMF, daylight observations.	Domestic cattle across the globe, and grazing and resting roe and red deer, align their body axes in roughly a N-S direction. Roe deer orient their heads northward when grazing or resting. At high magnetic latitudes, magnetic North was a better predictor of alignment than geographic North.
Burda et al. 2009: As in Begall et al. 2008, including 153 localities/herds (cattle) and 47 localities/herds (roe deer) within 150 m of high voltage powerlines	Separate analysis of orientation of animals near high voltage powerlines, exposed to the GMF and power frequency electric and magnetic fields and corona ion disturbances of the atmospheric electric field.	The natural N-S orientation of cattle and deer was disrupted, with random orientation within 150 m of high voltage powerlines. However, directly under powerlines animals aligned themselves E-W under E-W lines, N-S under N-S lines and randomly under NE-SW or NW-SE lines. Furthermore, the alignment of cattle as a function of distance from E-W lines progressively rotated from E-W under the line to N-S at distances >150 m away. In the case of E-W powerlines, cattle and deer oriented better on the north side compared with the south side. Overall, the evidence supports a magnetic compass in cattle and deer based on an intensity-dependent mechanism.

*This corresponds to the Larmor frequency for the free electron in the local GMF

Vácha et al. 2009 J Exp Biol 212:3473-3477. Ritz et al. 2009 Biophys J 96:3451-3457. Begall et al. 2008 PNAS 105:3451-13455 Burda et al. 2009 PNAS 106:5708-13

I point also to the findings of Begall et al 2008 and Burda et al 2009

The ICNIRP Exposure Limit is:

- 0.92 muT at 1 MHz
- 0.092 muT between 10 – 400 MHz
- 0.2 muT at 2 GHz

Note that RF disruption of the animal compass occurs at levels below the ICNIRP limit

Ritz T, Wiltschko R, Hore PJ, Rodgers CT, Stapput K, Thalau P, Timmel CR, Wiltschko W. 2009. Magnetic compass of birds is based on a molecule with optimal directional sensitivity. *Biophysical Journal* 96, 3451–3457. (doi:10. 1016/j.bpj.2008.11.072)

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Slide 33

Effects of animal magnetic compass orientation with RF and ELF EMF exposures (GMF = geomagnetic field). Continued:

Study	MF and light exposure	Findings
Vácha et al. 2009: American cockroaches: 11 individually isolated from each other.	Local GMF 42.9 μ T, inclination 64°. white light: (i) These conditions as control (ii) GM North was rotated 60° in 5 min intervals Adding vertically to both of these: (iii) 1.2 MHz, 0.044 μ T, red light (iv) 2.4 MHz, 0.044 and 0.018 μ T (v) 7 MHz, 0.044 μ T	Cockroaches were tested for locomotive activity using double-blinded procedure. 1. Changes in activity between stable and 60° periodic field rotations, indicating functionality of basic MF sense; 2. 1.2 MHz interfered with above changes, disruption threshold between 12 – 18 μ T; 3. 2.4 MHz interfered with above changes, disruption threshold between 12 – 18 μ T; 4. 7 MHz produced no disruption at 44 nT.
Ritz et al 2009: European robin <i>Erithacus rubecula</i> : 12 individual tested in spring migration season	nm green 48 μ T n 1.315 and	1. GMF of 46 μ T: (i) GMF alone: well orientated, (ii) 0.01 and 0.03 MHz: no interference, (iii) 0.1 and 0.5 MHz: weak axial response characteristic of compass on its limit of operation, (iv) 0.658 MHz and higher: disorientation, (v) Larmor frequency of 1.315 MHz: disoriented even at 15 nT, not affected at 5 nT. 2. Static field set artificially at 92 μ T, 10.9% μ T alone: well orientated, (i) 1.315 MHz at 150 or 48 nT orientation no longer affected, (ii) 2.63 MHz: disorientation at 15 nT.
Begall et al. 2008: Worldwide observations: 8,510 Domestic cat 308 pastures and 2,074 Roe deer 241 localities		Domestic cats across the globe, and grazing and resting roe and red deer, align their body axes in roughly a N-S direction. Roe deer orient their heads northward when grazing or resting. At high magnetic latitudes, magnetic North was a better predictor of alignment than geographic North.
Burda et al. 2009: As in Begall et al 2008, including 153 localities/herds (cattle) and 47 localities/herds (roe deer) within 150 m of high voltage powerlines	Separate analysis of orientation of animals near high voltage powerlines, exposed to the GMF and power frequency electric and magnetic fields and corona ion disturbances of the atmospheric electric field.	The natural N-S orientation of cattle and deer was disrupted, with random orientation within 150 m of high voltage powerlines. However, directly under powerlines animals aligned themselves E-W under E-W lines, N-S under N-S lines and randomly under NE-SW or NW-SE lines. Furthermore, the alignment of cattle as a function of distance from E-W lines progressively rotated from E-W under the line to N-S at distances >150 m away. In the case of E-W powerlines, cattle and deer oriented better on the north side compared with the south side. Overall, the evidence supports a magnetic compass in cattle and deer based on an intensity-dependent mechanism.

(Note: A red arrow points from the 'Study' column to the 'Findings' column for the Vácha et al. 2009 study, specifically to the text 'disruption threshold between 12 – 18 μ T'. A red circle highlights this text.)

***This corresponds to the Larmor frequency for the free electron in the local GMF**

Vácha et al. 2009 J Exp Biol 212:3473-3477. Ritz et al. 2009 Biophys J 96:3451-3457. Begall et al. 2008 PNAS 105:3451-13455 Burda et al. 2009 PNAS 106:5708-13

I point also to the findings of Begall et al 2008 and Burda et al 2009

The ICNIRP Exposure Limit is:

- 0.92 μ T at 1 MHz
- 0.092 μ T between 10 – 400 MHz
- 0.2 μ T at 2 GHz

Note that RF disruption of the animal compass occurs at levels below the ICNIRP limit

Ritz T, Wiltschko R, Hore PJ, Rodgers CT, Stapput K, Thalau P, Timmel CR, Wiltschko W. 2009. Magnetic compass of birds is based on a molecule with optimal directional sensitivity. *Biophysical Journal* 96, 3451–3457. (doi:10. 1016/j.bpj.2008.11.072)

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Slide 34

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More underlying biology.....

What links these apparently disparate EMF health outcomes?

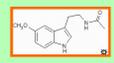
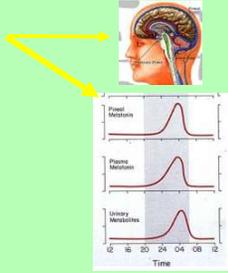
- Childhood leukaemia
- Adult leukaemia
- Adult brain tumours
- ALS (motor neurone disease)
- Miscarriage & adverse birth outcomes
- Depression & depressive symptoms
- Alzheimer's disease
- Breast cancer

They could all be explained by
Melatonin & circadian rhythm
disruption by
electric & magnetic fields

Circadian rhythm & melatonin* disruption

- could potentially explain many of the EMF health effects

- Melatonin, a key component of circadian rhythms, is produced in the pineal gland mainly at night when light levels fall below ~200 lux
- Broad-spectrum, ubiquitously-acting antioxidant and anti-cancer agent, highly protective of oxidative damage to the human haemopoietic system¹ – **relevant to leukaemia**
- Disruption by light-at-night associated with (i) increased cancer risk in animals and in humans, (ii) with **depression, Alzheimer's disease and possibly miscarriage**
- Stevens (1987)² proposed that exposure to **light-at-night and EMF** may increase breast cancer risk, by melatonin disruption
- Night-shift workers have about 50% increased risk of breast cancer
- **IARC 98 (2010) has classified night-shift work as a Class 2A Probable carcinogen**



¹Vijayalaxmi et al 1996 Mutation Research 371:221-228; ²Stevens 1987. Am. J Epidemiol. 125:556-61. *N-acetyl-5-methoxytryptamine

The adverse health effects associated with ELF MF exposure could all potentially be explained by circadian rhythm disruption

Melatonin is a broad-spectrum, ubiquitously-acting antioxidant and anti-cancer agent. Which also reduces growth of human myeloid leukemia cells and whose disruption by light-at-night is associated with increased cancer risk.

Magnetic field disruption of melatonin, pineal cells, cryptochromes and circadian rhythms

- **in humans**
Not revealed in volunteer short exposures to pure AC MFs
Seen in populations exposed to "real" EMFs¹ – down to 0.2 μ T
- **in animals**
Most effects observed with non-smooth AC MFs
Strong findings in cows and sheep with "real" EMFs²
- **on pineal cells**
Small but detailed literature – action in synthesising melatonin disrupted. Some animals have MF compass in the pineal gland

Circadian rhythms are controlled by Clock genes
– the gene *Cry1* codes the Cryptochrome³ protein molecule, CRY1, in the eye, which in turn is involved in the regulation of circadian rhythms.

Cryptochrome acts as the magnetic compass in animals

Interactions of the post-ganglionic sympathetic neuron with the pinealocyte and the synthesis of melatonin. Each of the numbered sites has been reported to be influenced by magnetic fields³.

¹Henshaw & Reiter 2005 BEMs Suppl 7:586-597
²Burda et al 2009. ELF-MFs disrupt magnetic alignment of ruminants. PNAS 106:5708-13. ³Evolved ~2.5 bn years (Gu 1997 Mol Biol Evol 14:861-866)

Yoshii, Ahmad, Helfrich-Forster 2009 Cryptochrome mediates light-dependent magnetosensitivity of *Drosophila*'s circadian clock. PLoS Biol 7(4): e1000086. doi:10.1371/journal.pbio.1000086

So what about magnetic field effects on melatonin, pineal cells, cryptochromes and circadian rhythms?

Melatonin disruption in humans is really seen in populations exposed to "real" fields – down to 0.2 μ T

Similarly in animals, effects are seen in "real" fields, both in the laboratory and outdoors

There's a small but detailed literature - that MFs interfere with the action of pineal cells in synthesising melatonin.

The human light-detection threshold is sensitive to MF exposure

But most importantly, cryptochrome, expressed by the CRY genes **controls the mammalian circadian clock and acts as the magnetic compass in animals.**

And I will be saying more about that later.

Note:

There are 8 Clock genes in humans: PER1, PER2, CLOCK, BMAL1, CRY1, CK1 δ /e, CRY2, BMAL2 (see Cermakian & Boivin 2003)

Gu Age of Eukaryotes & Prokaryotes 2.1-2.9 billion yrs Mol Biol Evol 14;861-66

Are human cryptochromes magnetosensitive? - Yes

Foley, Gegear & Reppert 2011 Nature Comm ncomms1364:

"Human cryptochrome exhibits light-dependent magnetosensitivity"

- **Study:** Magnetic behavioural response of CRY-deficient and hCRY2 *Drosophila melanogaster* (10 – 12 groups of 100-150 individual flies per test), under control of *tim-GAL4 driver*.
- **Methods:** Flies exposed between 10 – 500 μ T with full spectrum and blocked (>500 & >400 nm) light
- **Findings:** (i) CRY-deficient flies showed no MF response; (ii) Human CRY-rescued flies showed light-dependent magnetosensitivity; positive response under full spectrum light was blocked at >500 nm but partially restored at >400 nm.

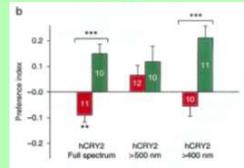
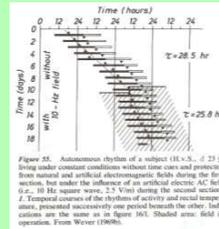


Figure 1b

Electric fields also affect circadian rhythms in humans

Wever (1979)*: In a long series of experiments, human volunteers were exposed for several weeks to 10 Hz square wave **electric fields** of only **2.5 V/m**. The 24 h circadian rhythm was disrupted. Volunteers were immediately entrained to the external signal. Effect lasted for a few days, indicating E-fields acting as zeitgebers



*Wever 1979. The circadian system of man. In: Results of Experiments Under Temporal Isolation. Schaefer KE, ed. Springer-Verlag, New York

Magnetic fields and routes to cancer

- | | | |
|-------|---|---|
| (i) | Magnetic particles | Mechanical stress or free radical damage via the RPM |
| (ii) | Cryptochromes (in the eye) | Circadian rhythm disruption |
| (iii) | Cryptochromes (in peripheral blood cells) | Free radical damage by the RPM |
| (IV) | Genomic instability | Clearly relevant to cancer as it might lead to accumulation of mutations required for cancer formation* |

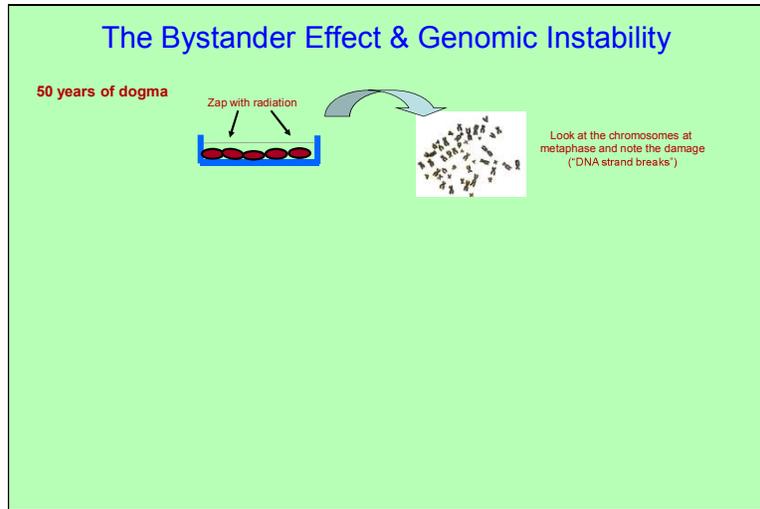
*Luukkonen et al 2014 Mutation Research 760:33-41

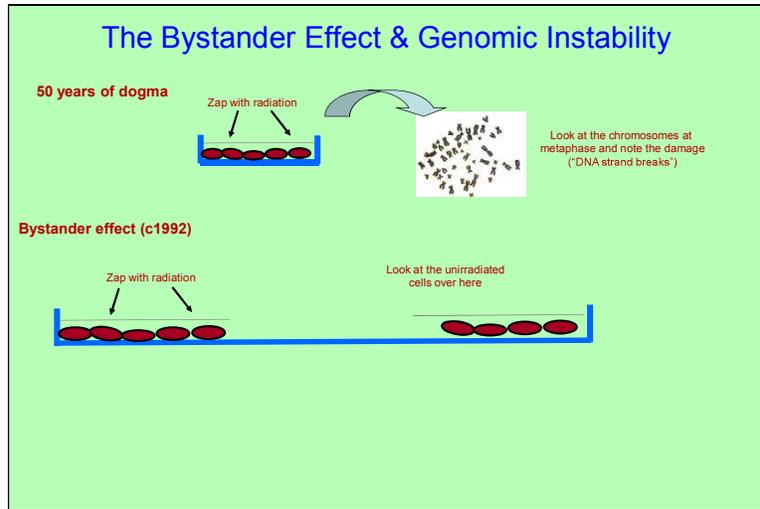
Some other key MF effects relevant to childhood leukaemia and cancer

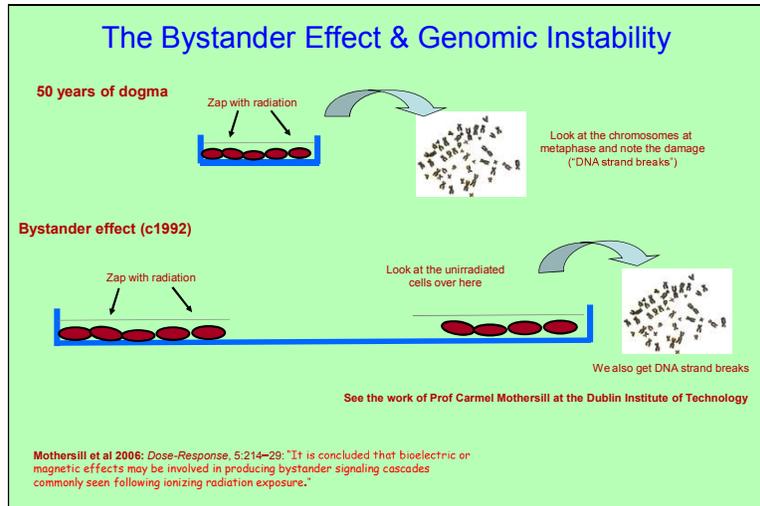
MFs Release reactive oxygen intermediates in human cord blood-derived monocytes (Lupke et al 2004. *Free Rad. Res.* 38:985–993) - **This alone would provide a model of how MFs increase childhood leukaemia risk***

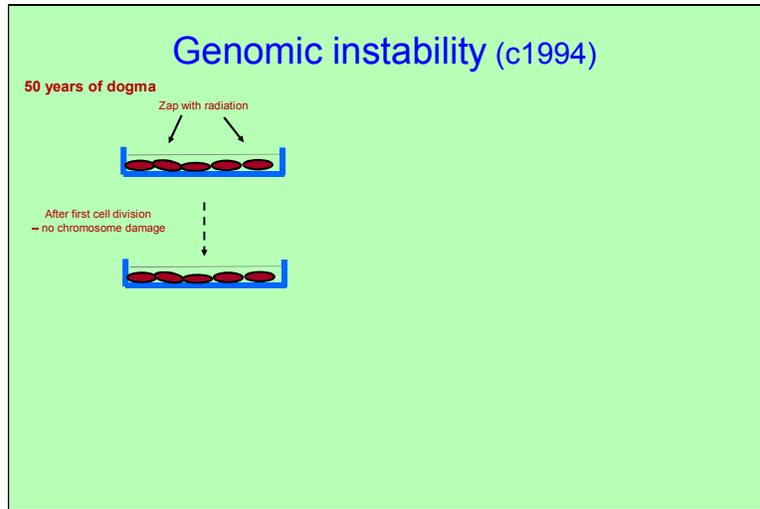
Induction of **genomic instability, oxidative processes**, and mitochondrial activity by 50 Hz magnetic fields in human SH-SY5Y neuroblastoma cells. [Luukkonen et al 2014 Mutation Research 760:33-41](#) - **Clearly relevant to cancer, first observed with ionising radiation, now with magnetic fields**

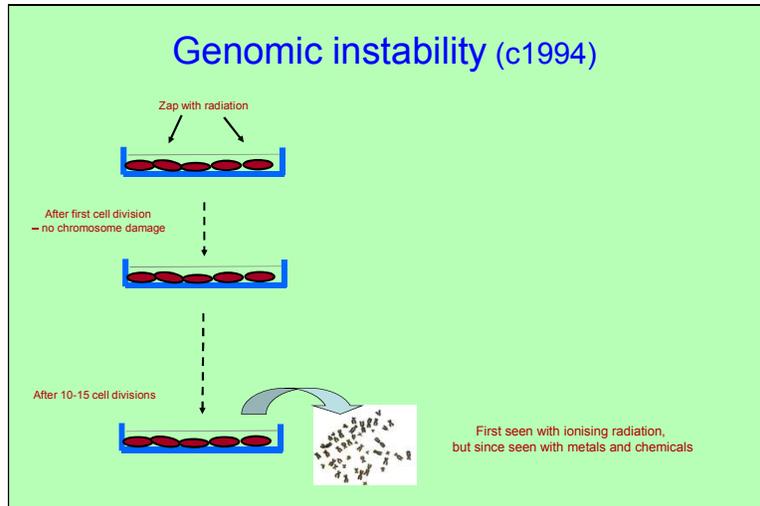
*IARC Report no 102, 2013 states that there are well performed studies showing induction of ROS and oxidative DNA damage by RF EMFs

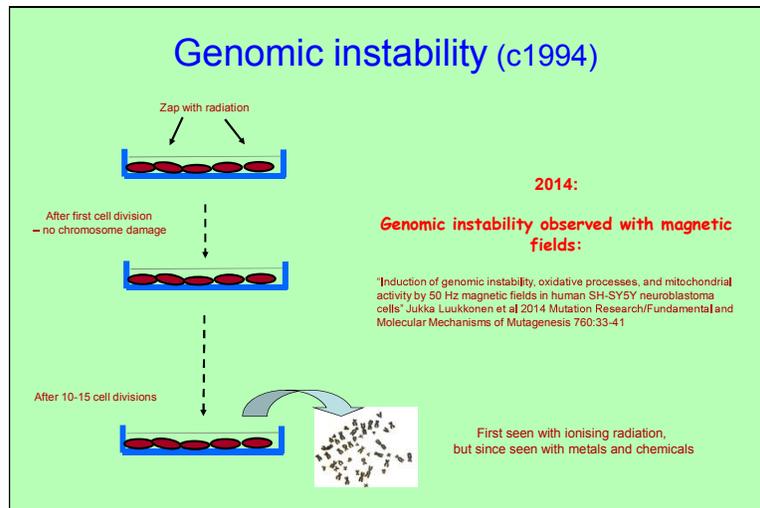












Summary

- Biological studies show that magnetic fields **have key hallmarks of a carcinogen**
- Epidemiological studies strongly associate magnetic field exposure with **a range of adverse health outcomes**
- Precaution against EMF exposure **is highly warranted and cost-beneficial**

In the case of high voltage overhead powerlines, the solution is to bury the lines over populated areas. This eliminates the electric fields and corona ions, and can strongly attenuate magnetic fields

Slide 50

Acknowledgements

Marian Harkin MEP and her colleagues

Illia Solov'yov (Illinois)
Jonathan Woodward (Tokyo)
Mike O'Carroll

and

Children with Cancer UK

Web version: [REDACTED]

Session 7, Wed 25th April 2012: www.childhoodcancer2012.org.uk

[REDACTED]



CHILDREN
with
CANCER UK
Registered Charity No. 298803

Last slide

Summary of O'Carroll & Henshaw 2008

Risk Analysis 28:225-234.

Leukaemia:

Report	Number of independent studies	Positives	Significant positives
IARC 2002	33	23.5 ($p < 0.01$)	9 ($p < 10^{-7}$)
California 2002	43	32 ($p < 0.001$)	14 ($p < 10^{-12}$)

There were no significant-negative results in either IARC or CHD list.

Results for adult brain cancer gave a similar, but less clear, message.

*Aggregating all the studies suggests that results for childhood leukemia are not stronger, numerically, than those for adult leukemia. CDHS did not note the number of significant-positives, but noted the meta-analytic summary and the number of positives, forming a view about the strength of these findings.

IARC shows no evidence of considering the aggregation of results other than subjectively. It considered individual studies but this led to a tendency to fragment and dismiss evidence that is intrinsically highly significant*

Bioinitiative 2012:
- a biologically-based EMF Report
<http://www.bioinitiative.org>

SECTION 13: Page 16: III. ALZHEIMER'S DISEASE

A. Possible Biologic Pathways from ELF MF Exposure to Alzheimer's Disease

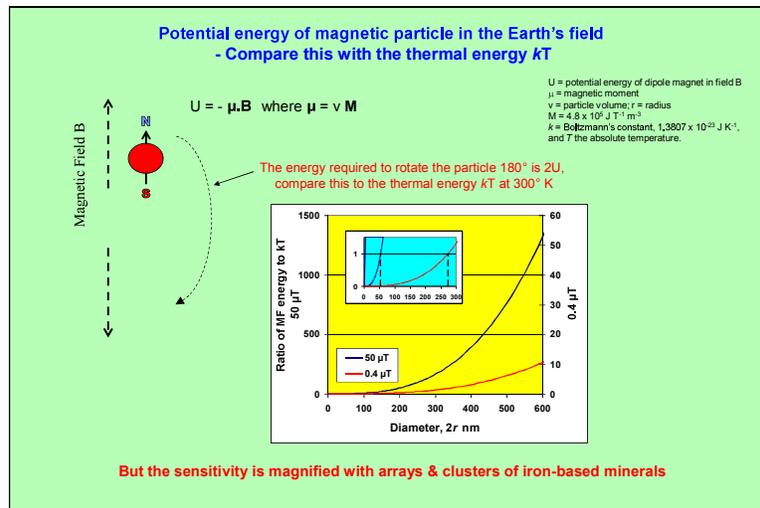
A.1. Over-Production of Peripheral Amyloid Beta Caused by ELF MF Exposure

***Conclusion:** There is now evidence that (i) high levels of peripheral amyloid beta are a risk factor for AD and (ii) medium to high ELF MF exposure can increase peripheral amyloid beta. High brain levels of amyloid beta are also a risk factor for AD and medium to high ELF MF exposure to brain cells likely also increases these cells' production of amyloid beta.*

Alzheimer's disease is linked to reduced melatonin production in the elderly

OXIDATIVE DAMAGE IN THE CENTRAL NERVOUS
SYSTEM: PROTECTION BY MELATONIN
RUSSEL J. REITER, Progress in Neurobiology Vol. 56, pp. 359 to 384, 1998

A selected extract from the 2012 Bioinitiative report



Magnetite can readily transduce a 0.4 μT 50 Hz field
 See: Vanderstraeten J. Gillis P. 2010. Theoretical Evaluation of Magnetoreception of Power-Frequency Fields. Bioelectromagnetics 31:371-379

Common question: Given that we are all exposed to the geomagnetic field of $50 \mu\text{T}$,
how can a 100 nT fluctuation or a $50 \text{ Hz } 0.4 \mu\text{T}$ field make any difference?

Turtles

- Kloc et al 1996 Reported that turtles with magnets on their shells when released well away from their nesting sites were initially confused.
- However, they eventually found their way back to their nesting sites

- see Irwin & Lohmann 2003 J Exp Biol 206:497-501; Lohmann et al 2011 Curr Opin Biol 22:1-7



7,400 μT near the poles

Pigeons Mora and Walker 2012 doi:10.1016/j.anbehav.2012.05.005

- Homing pigeons with $2,500 \mu\text{T}$ magnets on their beaks.
- Released from 26 sites up to 42 km from their loft.
- Initially flew to the right of their homing direction
- This was corrected within 2.5 km
- No effect on the speed or success of homing



NdFeB magnets, $2,500 \mu\text{T}$, 50 times GMF
1-4 year olds, trained to home from 40 km
Up to 40 pigeons in repeated releases

Now a common question that physicists ask is how can a field of $0.4 \mu\text{T}$ (at ELF frequency) make any difference alongside the existing DC field from the Earth?

The results of these studies show that turtles and pigeons respond changing magnetic fields and are not disturbed by a static (DC) field.

Static MFs alter circadian rhythms via cryptochromes

Yoshii *et al* 2009 (PLoS Biol 7(4): e1000086)

Study: *Drosophila melanogaster*: 23-29 flies per group; mean circadian period under blue light 25.8 ± 0.14 h.

Methods: Wild type flies exposed 0 and 300 μ T, red light, then 0, 150, 300, 500 μ T, blue light plus:
 (i). FAD impaired (*cryb*)
 (ii). Mutants lacking CRY (*cryOUT*)
 (iii). Clock-gene promoter/CRY over-expressed (*tim-gal4/vas-cry*) flies

Findings: No MF effect under red light. Under blue light circadian rhythm lengthened >0.5 h at 300 μ T and (i) *cryb*: no MF effect; (ii) *cryOUT*: no MF effect and (iii) *tim-gal4vas-cry*: at 300 μ T, 2 h period lengthening and most flies arrhythmic

What about effects in humans?

Wever (1979): In a long series of experiments, human volunteers were exposed for several weeks to 10 Hz square wave electric fields of only 2.5 V/m. The 24 h circadian rhythm was disrupted. Volunteers were immediately entrained to the external signal. Effect lasted for a few days, indicating E-fields acting as zeitgebers

FAD = flavin-adenine dinucleotide

Figure 21. Autonomously recorded rhythm of a subject (H x S, 23 y) living under constant conditions without time cues and protected from natural and artificial electromagnetic fields during the first section, but under the influence of an artificial electric AC field (i.e., 10 Hz square wave, 2.5 V/m) during the second section. J. Temporal courses of the rhythms of activity and rest; temperature, presented successively one period beneath the other. Indications are the same as in Figure 161. Shaded area: field in operation. From Wever (1966).

Wever 1979. The circadian system of man. In: Results of Experiments Under Temporal Isolation. Schaefer KE, ed. Springer-Verlag, New York

Here I talk through the significance that cryptochromes control circadian rhythm Yoshii T, Ahmad M, Helfrich-Förster C (2009) Cryptochrome mediates light-dependent magnetosensitivity of *Drosophila*'s circadian clock. PLoS Biol 7(4): e1000086.

doi:10.1371/journal.pbio.1000086

FAD = flavin-adenine dinucleotide

Light, cryptochrome expression and reduced plasma melatonin

Chen *et al* 2005 [*Pediatric Research* 58:1180-1184] – 61 jaundiced full term neonates*:

- Jaundiced neonates treated by blue light exposure with the eyes covered*

- **Expression** of circadian genes: *Bmal1* and *Cry1* in peripheral blood mononuclear cells and **reduction** in plasma melatonin

- Reduction in plasma melatonin usually interpreted as reduced **production** in the pineal gland

- Could indicate increased **consumption** in quenching free radicals in the bloodstream

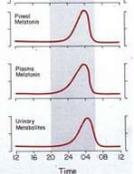
- Could it be that the blue light also creates **radical pairs** in the cryptochromes, so that plasma melatonin was **consumed** in quenching these radicals?

- If so, could **environmental MFs** exacerbate this effect – resulting in increased radical damage to blood cells?

*Zhejiang Children's Hospital. 24 h exposure to 5,500 – 7,200 lux from 12 x 20 W fluorescent light bulbs

**Circadian rhythms & melatonin* disruption
and cancer risk**
- could potentially explain many of the EMF health effects

- Stevens (1987)¹ proposed that exposure to light-at-night and EMF may increase breast cancer risk, by melatonin disruption
- Night-shift workers have ~50% increased risk of breast cancer
- IARC 98 (2010) night-shift work 2A Probable Carcinogen



Melatonin produced in the pineal gland at night when light levels fall below ~200 lux

*Broad-spectrum, ubiquitously-acting antioxidant and anti-cancer agent, highly protective of oxidative damage to the human haemopoietic system²

¹Stevens 1987. *Am. J. Epidemiol.* 125:556-61. ²Vijayalaxmi et al 1996 *Mut Res* 371:221-8

The adverse health effects associated with ELF MF exposure could all potentially be explained by circadian rhythm disruption

Melatonin is a broad-spectrum, ubiquitously-acting antioxidant and anti-cancer agent. Which also reduces growth of human myeloid leukemia cells and whose disruption by light-at-night is associated with increased cancer risk.

Richard G. Stevens 2012 Hypothesis: Does electric light stimulate cancer development in children?
Cancer Epidemiology Biomarkers & Prevention, doi:10.1158/1055-9965.EPI-12-0015

Some MF effects *in vitro*

1. At high fields - 1 mT 50 Hz:

Release of reactive oxygen intermediates in human cord blood-derived monocytes (Lupke et al 2004. *Free Rad. Res.* 38:985-993)

Enhance cell proliferation and DNA damage in HL-60 human leukaemia cells (Wolf et al. 2005 *Biochim Biophys Acta* 1743 :120-9)

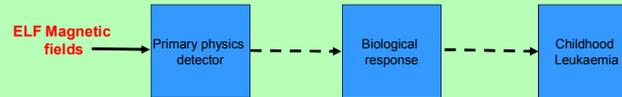
2. At environmentally relevant fields:

Stress response induced in HL-60 cells (10 μ T, 50 Hz: Tokalov & Gutzeit 2004. *Environ. Res.* 94:145-51)

A gene-environment analysis in 123 childhood ALL patients revealed an association between DNA repair enzymes and average MF exposure of 0.18 μ T.
- Yang et al. 2008 *Leuk Lymphoma* 49:2344-50 - Shanghai School of Medicine

Epidemiological Studies show a doubling of **Childhood Leukaemia** risk associated with average 0.3/0.4 μ T, 50/60 Hz magnetic field exposure – and links with other adverse health outcomes too...

Is the magnetic field association with childhood leukaemia causal?



Some MF effects *in vitro*

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Release of reactive oxygen intermediates in human cord blood-derived monocytes (Lupke et al 2004. *Free Rad. Res.* 38:985-993)

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- An evidence-based possible cause of childhood leukaemia should in any reasonable interpretation for the public mean an adverse effect. People don't want to expose their children to an evidence-based possible cause of childhood leukaemia, even if there isn't not a fully proven cause.
- Further down the web page, this paragraph (which is given in quotes in the article) is blatant spin by the well used but crude technique of saying what was NOT said but hiding what WAS said:
- "National and international health and scientific agencies have reviewed more than 30 years of research into electromagnetic fields. None of these agencies has concluded that exposure to electromagnetic fields from power lines or other electrical source is a cause of any long-term adverse effects on human, plant or animal health."
- They did of course conclude on the basis of evidence that the exposure was a possible cause.

The RPM may act due to the MF around magnetite particles
- increasing the lifetime of free radicals

Chignell & Sik 1998 (Photochem Photobiol 68: 598-601):

1 μm Magnetite particles encapsulated in polystyrene dramatically decreased the time for 50% haemolysis of UV irradiated human erythrocytes.

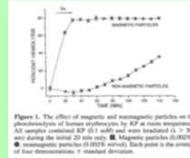
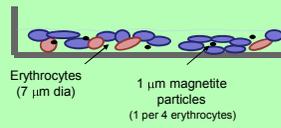
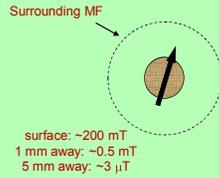


Figure 1. The effect of magnetic and nonmagnetic particles on the photohemolysis of human erythrocytes by UV at room temperature. 0.2 μm diameter SP (0.1 μm dia) and iron (magnetite) (1 μm dia) during the initial 20 min only. ■ Magnetite particles (0.0025 μm); ● nonmagnetic particles (0.0025 μm); each point is the average of four determinations \pm standard deviation.

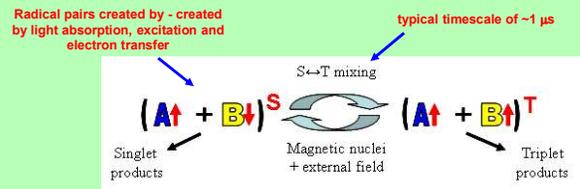


Binhi 2008 (IJRB 84:569-79): - Hypothesised childhood leukaemia arose from SP magnetite particles in blood which transduced/amplified 50 Hz fields, creating free radicals by the RPM

A second mechanism of low level MF detection

- Low intensity MFs can increase the lifetime of free radical pairs making them potentially more available to cause biological damage

They do so by altering the spin states of radical pairs
-Increasing the rate of transition from the short-lived **singlet (S)** to the longer-lived **triplet (T)** state

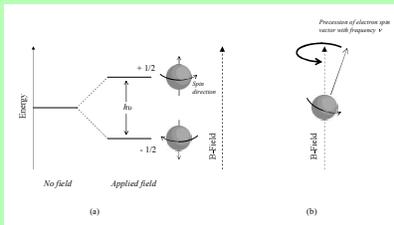


This is known as the Radical Pair Mechanism, RPM

Introduction to RPM – Zeeman splitting and Larmor precession



Zeeman Effect 1896
In a static MF, get splitting of spectral lines due to the electron spin



(a) No field Applied field (b) Precession of electron spin vector with frequency ν

The equivalent classical model has the electron spin vector precessing at the Larmor frequency of 1.4 MHz at 50 μ T

Get resonant absorption (ESR) at frequency ν = 1.4 MHz at 50 μ T

**At the GM field in Nottingham, 50 μ T:
- $h\nu$ is $\sim 10^{-7}$ of thermal energy kT**



Pieter Zeeman
(1865-1943)



Joseph Larmor
(1857-1942)

As an introduction to the RPM this slide goes back to basics

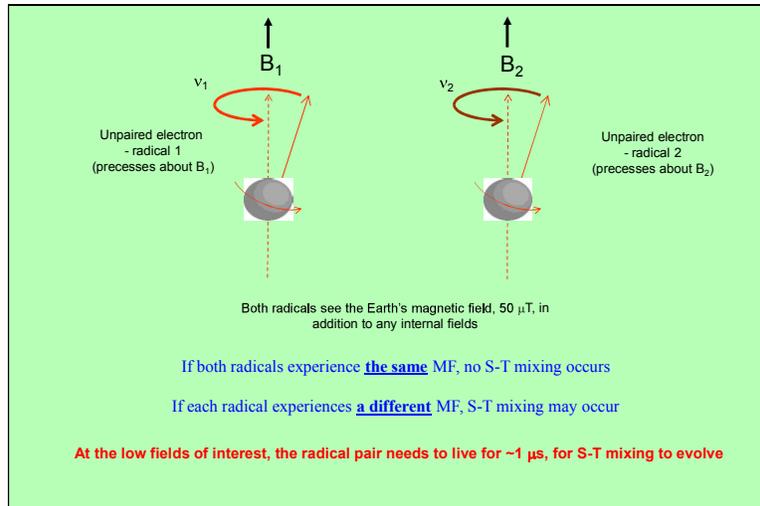
On the left we see the familiar Zeeman effect. If you put an electron in a static magnetic field, it will align its spin vector either up or down with respect to the field direction.

This energy difference between these states may be represented by a photon of energy $h\nu$ where h is Planck's Constant and ν is the photon frequency. A spectroscopic transition can be induced between these energy states by applying radiation at the correct frequency. At 50 μ T, $\nu = 1.4$ MHz.

I am showing this to point out that the energy difference is $\sim 10^{-7}$ of the thermal energy kT . i.e. the phenomenon is not only well below kT , but it has nothing to do with classical energies, rather we are talking about the quantum-mechanical interaction of the magnetic field with the electron spin.

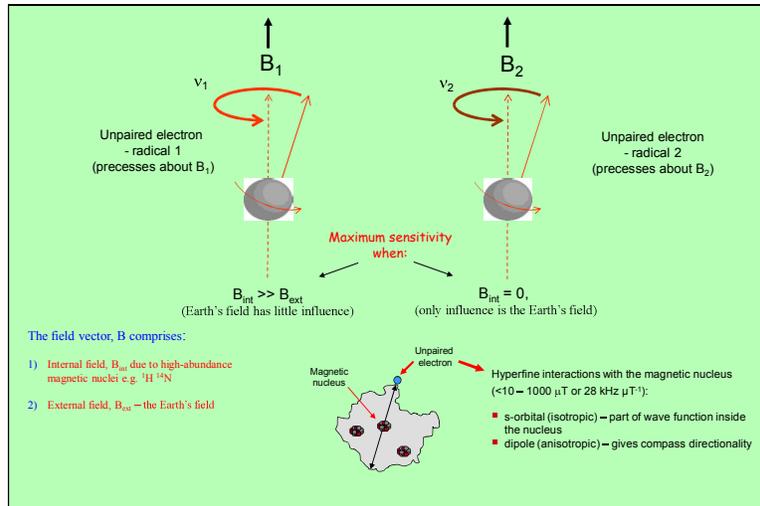
On the right is the classical physics model of this, taken from NMR & MRI, that the electron is precessing about the magnetic field at frequency ν , 1.4 MHz, the so-called Larmor frequency. I will be using this model in a moment.

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Here I talk through how RP mixing occurs, using the precession model

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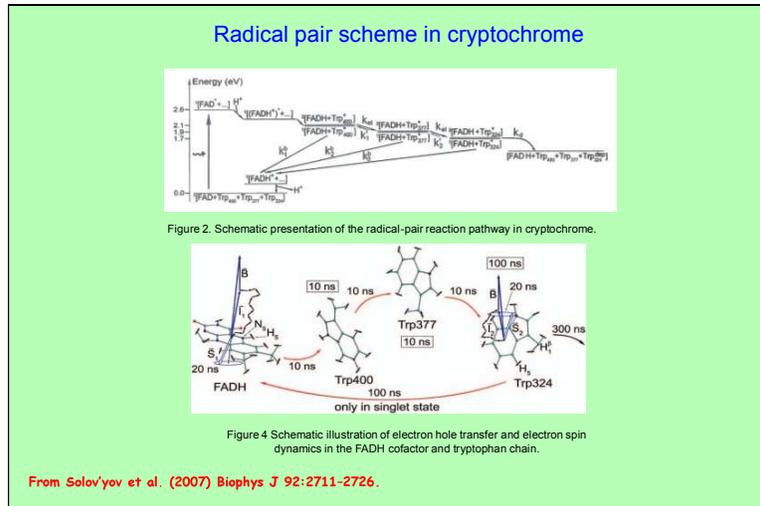


Continued:

The field vector, B has two components: (i) due to **high-abundance magnetic nuclei** e.g. 1H ^{14}N , and (ii) due to the **Earth's field**.

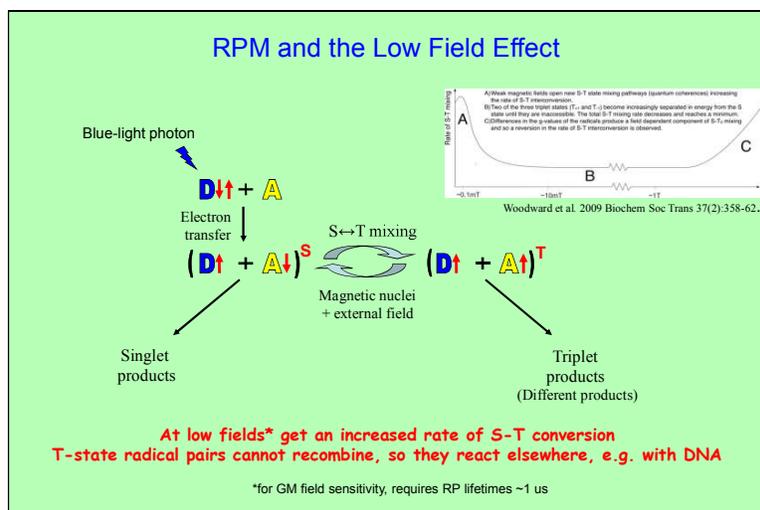
For a compass, maximum sensitivity occurs when the Earth's field has little influence on precession on radical 1, but is the only influence on radical 2

The precession is governed by hyperfine interaction with the proton in the nucleus, consisting of an isotropic S-wave, or S-orbital interaction, and an anisotropic dipole interaction.



I've slipped this slide in here to point out models of the actual RP pathways in cryptochrome

FAD = flavin-adenine dinucleotide



Low fields open up new S-T mixing pathways increasing the rate of S-T conversion

Examples of RPM in chemical systems:

- Scaiano et al 1997: Photoreduction of benzophenone by 1,4-cyclohexadiene;
- Mohtat et al 1998: Radical pair derived from hydrogen abstraction of triplet benzophenone;
- Streiner & Ulrich 1989: Table 6 (Molecular crystals): e.g. Naphthalene, 1,4-dibromonaphthalen, anthracene; Table 5: e.g.s of photochemical reactions in the gas phase
- Brocklehurst & McLauchlan 1996: benzaldehyde (PhCHO, Ph = C₆H₅) in tetrachloromethane; RPs created from UV irradiation of the condensed ring aromatic hydrocarbon pyrene (Py) in solution with 1,3-dicyanobenzene (DCB)
- Vink & Woodward (2004): Radical recombination reaction occurring after the photodecomposition of 2-hydroxy-4-(2-hydroxyethoxy)-2-methylpropiophenone (R-HP)
- Woodward et al 2002: Pyrene with isomers of dicyanobenzene

References:

Steiner UE, Ulrich T. 1989, Magnetic field effects in chemical reactions and related phenomena. Chemical Reviews, 89:51-147.
 Brocklehurst R, McLauchlan KA 1996. Free radical mechanism for the effects of environmental electromagnetic fields on biological systems. International Journal of Radiation Biology 69:3-34.

Timmel CR, Till U, Brocklehurst B, Mclauchlan KA, Hore PJ 1998. Effects of weak magnetic fields on free radical recombination reactions. *Molecular Physics* 95:71-89.

Woodward JR 2002. Radical pairs in solution. *Progress in Reaction Kinetics and Mechanism*, 27:165-207.

Timmel CR, Henbest KB 2004. A study of spin chemistry in weak magnetic fields. *Philosophical Transactions of the Royal Society of London A* 362:2573-2589.

Rodgers CT 2009. Magnetic field effects in chemical systems, *Pure and Applied Chemistry* 81:19-43.

Rodgers CT, Hore PJ, 2009. Chemical magnetoreception in birds: The radical pair mechanism. *Proceedings of the National Academy of Sciences of the USA* 106:353-360.

Opening Floor Meeting Norwich to Tilbury 12th February 2026 at Orsett, Essex.

Firstly, I'd like to take this opportunity to thank this panel and acknowledge the phenomenal work Rosie Pearson and her committee do, their unwavering commitment to protecting the environment and communities along this 180km swathe, the endless support she and her team has shown to communities (all voluntary) fighting for better outcomes than the status quo.

Also drawing your attention to the fact that this group is not trying to delay this project or increase its cost but in fact find better alternatives that will reduce the **harm** this project will cause. Please read their report 'Leaders not Laggards' showing better alternatives to pylons and HVAC.

National Grid at every press release possible have quoted offshore or undergrounding is 5 to 10 times more expensive but when you're not pricing works using the Treasury Green Book analysis you can make any project seem cheaper – therefore this project will most definitely go over budget.

We should be insisting on an independent audit, using the TG book - to protect the environment, communities and for best practice - best outcome. NG state they have their own book (but obviously with different words to the Govt version) public money is being spent so the TG book should be applied!

Costs missing are:-

BNG (Biodiversity Net Gain regulations)

Community benefits,

NG have allowed 10% contingency even though TG book states 40% on larger projects.

House and Business impact

Plus Natural Capital impact.

When comparing other projects like Hinkley Point and scaling this up to 180km and applying the Treasury Green book, the Norwich and Tilbury project will equate to a cost well over £8bn. This shows that the National Grid narrative is pylon whatever the cost...

I have attended numerous consultations over the last few years and asked the same questions,

What impact will these pylons have on peoples health (not just mental health as you can see that firsthand at these hearings).

NG have failed to answer questions relating to living near pylons with pacemakers on numerous occasions -which is a personal issue to my family.

Pacemakers rely on electrical signals to regulate heartbeats so exposure to strong EMF can disrupt these signals – we have two pylons in close proximally to my boundary.

Staying with EMF (Electromagnetic fields), Prof Denis Henshaw states overhead lines were linked to "beyond reasonable doubt" childhood and adult leukaemia and adult brain tumours.

He also advised the UK government in 2007 not to build new houses near power lines – unfortunately ours are already here!

Draper report of 2004, found those living within 200 metres of the OHL were 70% more likely to develop the disease.

When harm outweighs the benefits caused by pylons and HVAC I would urge you to consider another hearing looking at alternatives like HVDC and using the Treasury Green Book please.

I hope you are able to take on board the full risk and harm that you have heard over the last few days and will reject this proposal in its entirety.

Thank you.

Pylons are NOT cheap.

Think overhead lines are the cheapest way? Think again.

Costings are not transparent, and Ofgem must do its duty as a consumer regulator to ensure that consumers are not short-changed.

Let's take a look at the 180km National Grid Norwich to Tilbury (N2T) proposal¹.

National Grid say the N2T project will cost c£900m. We say that's **nonsense**.

The likely real cost of the Norwich to Tilbury pylons project is over £8bn,

AND HERE IS WHY –

1. Comparatives.

Hinckley, a 57km project (of which 49km is pylons/overhead lines and 8.5km underground trenching) cost £600m in 2020².

Scaling this up, which is easy because the overhead line & underground proportions are similar, would result in Norwich to Tilbury costing £2.5bn in today's money – already significantly more than the stated £900m.

NGET's Bramford to Twinstead project is 29km long and cost £499m in 2023. That's for 18km of overhead lines and 11km of underground cables³. Even allowing for the fact that there is proportionally more undergrounding, are we really to believe that the six-times longer N2T costs less than double?

2. New costs.

Two **huge** new costs must be added to overhead line proposals:

- **Biodiversity Net Gain regulations**
- **Community Benefits**

*(Note that **neither** is applicable to an offshore grid, and benefits are much lower for undergrounding)*

We can make educated calculations about the costs of BNG or Community Benefits based on publicly available information⁴. We estimate some £600m.

¹ This includes 157km of pylons/overhead lines and 27km of underground trenching.

² With extra costs for T pylons removed.

³ Plus 1 substation, 4 sealing end compounds, removal of 25km 132kv and 2km 400kv.

⁴ There are many variables & permutations for both. For BNG it will depend on whether land is available under voluntary agreements or compulsory purchase, or whether NGET is forced to buy statutory credits – we have taken a middle ground, using the A12 as a useful linear project comparator. For Benefits, it will depend on amount and distance from project. Our Benefits guesstimate is based on the paper published by the previous Government.

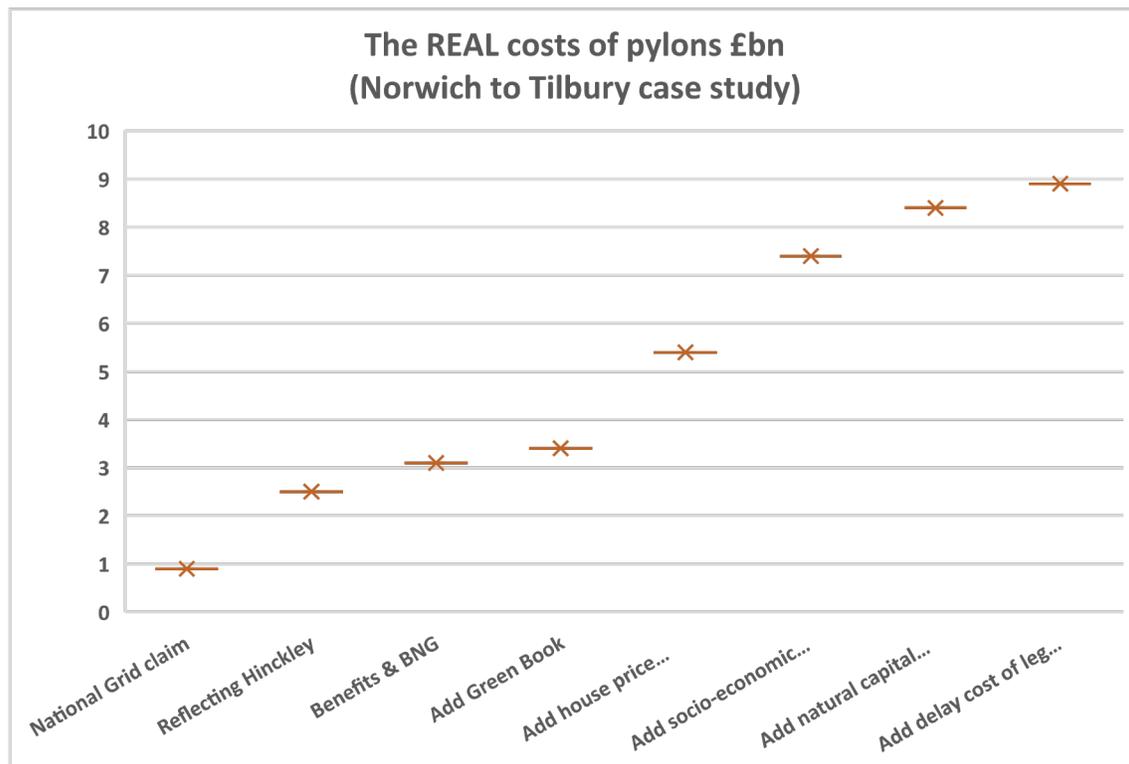
3. Treasury Green Book guidance is mandatory and should be followed.

Adherence to the Green Book would require –

- **A contingency of 40%** for a large infrastructure project. National Grid's N2T contingency is only 10%. This leaves no margin for error, despite the fact that this is also NG's longest – and therefore riskiest - onshore project. So, we need to add around another £300m.
- **An analysis of socio-economic impact (tourism, farms & businesses, house prices) and natural capital impact.** This impact must be quantified. House price impact alone could reach £2bn and the impact on businesses could be much higher.
Estimate £2bn for house price compensation⁵, + £2bn for impact on businesses, and £1bn for natural capital. (We need this to be calculated by National Grid).

True cost

Adding all these considerations to the mix would show the true, and very much higher, cost of pylons, as illustrated below –



⁵ Based on an average house price of £300k being reduced by 10% due to the Norwich to Tilbury project and number of households affected (77,000 notified by NGET). Actual average prices are higher and reductions can be around 40%, with mortgages declined.

Assumptions	£ bn		National Grid estimate	Realistic Costings	Offshore Grid
Hinkley (57km, £60	57 km	£0.6bn	0.9	2.4	2.5
Green Book	40%		0.1	1.0	1.0
A12 Costings	70%	£0.6bn		0.4	0.2
	30%			0.2	0.0
	10%	£23.1bn		2.3	0.0
	10%	£20.0bn		2.0	0.0
				1.0	0.5
TOTAL			1.0	9.3	4.2

Avg House value (£k)	Houses Impacted
300	77,000

National Grid Costing	0.9
Realistic Additional Cost	1.5
Contingency	1.0
Biodiversity Net Gain Cost	0.4
Loss of Natural Capital	1.0
House Price loss Compensation	2.3
Business/Tourism impact	2.0
Community Benefits Cost	0.2

