Witness Statement on Mobile Phone Radiation

- Andrew Goldsworthy

Andrew Goldsworthy was born in 1939. After a conventional Grammar School education he obtained a First Class Honors Degree in Botany followed by a PhD for research into plant physiology and biochemistry at the University of Wales. He went on to lecture at Imperial College London, where he spent the rest of his career. He has had many teaching and research interests, ranging from the biochemistry of photorespiration to the biology of space flight. He retired in 2004 but remains as an honorary lecturer. He was also a scientific advisor to the European Space Agency and is currently a scientific advisor to several European charities concerned with the environment and electromagnetic fields, including the Bio Electromagnetic Research Initiative, the Radiation Research Trust, and Electrosensitivity-UK. He has always had a strong interest in how living organisms use internally-generated electric currents to control their growth and metabolism, and in their disruption by externally-applied currents and fields. In his retirement, he pieced together nuggets of information from a wide range of scientific journals and created simple layperson's explanations of how weak electromagnetic fields affect us all. The first of these can be found at http://tinyurl.com/2nfujj. The present article was submitted at the request of the Canadian House of Commons Standing Committee on Health for a hearing on April 29th 2010 on the biological effects of microwave radiation".

Abstract

Many people suffer one or more of a wide variety of symptoms when exposed to weak non-ionising electromagnetic radiation, including that from cell phones and Wi-Fi. Those responsible for the radiation deny that these effects exist, saying that there is no plausible explanation. In this submission I explain just how these effects can arise, and how virtually all of them share one of two common mechanisms. The pieces of the jigsaw fit together remarkably well and leave little doubt that the majority of the reported effects are real and must be taken seriously. Knowledge of the mechanisms makes it possible to mitigate the worst of these effects and I have made a number of suggestions as to how this might be done. I have also explained how a simple test, taking just a day or two to perform, could be used to assess the biological safety of both new and existing wireless technologies. Until this has been done, it would be wise to halt the roll-out of new wireless technologies and withdraw from sale particularly hazardous items such as DECT baby monitors which radiate continuously next to a very young child.

Introduction

There are literally thousands of scientific papers written on the non-thermal effects of weak non-ionising radiation such as that from cell phones (www.bioinitiative.org). Well over half of them show some sort of biological effect, many with either direct or indirect implications for human health. However, the results lack consistency and the cell phone industry uses this to imply that there are really no ill effects and that it is all due to experimental error. This argument is, however, flawed because it does not take into account biological variability.

Biological variability

It is a common mistake made by physicists and engineers alike that living organisms behave like simple physical systems and must always respond in the same way to physical or chemical perturbations. Nothing could be further from the truth. Living cells are not just chemical factories run by a fixed computer program. They are the product of thousands of genes that interact in countless ways, both with each other and the environment. Their physiology changes continuously to cope with rapid alterations in the environment and there are also epigenetic changes to their DNA that can be semi-permanent over the lifetime of the whole organism. It is these characteristics that enable the genes from two different parents to adapt to one another and give a viable offspring rather than a genetic disaster. You could not take a random mix of components from an Apple Mac and a PC, throw them into a box and hope to get a machine that worked. However, living organisms do this sort of thing easily.

It follows that living cells and organisms cannot always be expected to respond in the same way to chemical insults or to electromagnetic radiation. For example, not every smoker dies of cancer and we do not all suffer the same (if any) side effects from taking a medicinal drug. We cannot therefore expect non-ionising radiation to affect everyone equally. Because not everyone is affected by the radiation does not mean that no one is. Although it is understandable why the Industry prefers to use this argument, it is deeply flawed and potentially dangerous to those who are susceptible to the radiation.

A new approach

A more realistic approach is to look at frequently reported effects of non-ionising electromagnetic fields to see if there are any underlying threads that may indicate a common mechanism and then to change the characteristics of the signal to minimise these effects.

I have tried to do this and have been moderately successful in that I have found two mechanisms, which together can explain most of the diverse health effects frequently reported as stemming from this sort of radiation. Both should be preventable or minimised by suitable modifications to the way in which the signal is modulated.

The first is due to effects on **cryptochrome**, which affect animal navigation, endogenous circadian rhythms and the immune system. The second is due to effects on **calcium efflux** from cell membranes. These include early dementia, multiple allergies, DNA fragmentation, loss of fertility, increased cancer risk and electromagnetic hypersensitivity.

Effects on cryptochrome

Cryptochrome is a ubiquitous pigment in animals and plants. Plants use it to sense light to optimise their ability to photosynthesise. Animals use it to sense the direction of the Earth's magnetic field. Both animals and plants also use it to regulate their body clocks, which anticipate dawn and dusk to switch metabolism between day and night modes. In animals, it regulates the sleep-wake cycle and also the immune system, which has peak activity during the night phase (Koukkari and Sothern 2006).

Unfortunately, radio waves badly upset the cryptochrome molecule to affect all of these functions. The energy doesn't come from the radio wave itself but from a previously absorbed high energy photon of light that flips an electron between two parts of the molecule to drive it into a high energy "free radical state". This decays spontaneously as the electron returns to the restore the *status quo*. Light intensity at any one time is perceived from the proportion of cryptochrome in the free radical state.

The direction of the Earth's magnetic field is detected because free radicals are magnetic and the rate at which the electron returns is determined by the orientation of the magnetic field in relation to the molecule. This time, the proportion of the cryptochrome in the free radical form is a measure of the strength and direction of the magnetic field. Both processes appear to be disrupted by radio frequency magnetic fields and the magnetic component of radio waves. In plants, radio waves are perceived as if they were light and have profound effects on their physiology. Animals that use the Earth's magnetic field for navigation may partially or completely lose that ability, which can account for colony collapse disorder in bees. The role of cryptochrome in the body clock means that this too can be disrupted by radio waves. Since the activity of the immune systems of both animals and plants are closely linked to the body clock, if the clock fails, their immune systems will not at any time function at full capacity. This will result in a reduced resistance to pathogens. It may also account for the increased incidence of cancer often reported around cell towers as the immune system becomes less able to deal with incipient cancer cells. I will not labour these points here since you should all have received an email from me giving a more detailed account of it together with a number of attachments containing the experimental evidence. Much of this evidence is very recent, the earliest being Ritz *et al* (2004) and most people are still unaware of it. Fortunately, the frequencies responsible (below about 10MHz) are outside the main cell phone frequencies, but occur as out-of-band frequencies arising from the transmission of harmonics of the main signal. They are therefore easy to filter out without loss of information carrying capacity. This has now been taken on board by the British Office of Communications (Ofcom), who are very much "on the ball" and asked for (and was given) my permission to pass it on to the UK operators.

Calcium efflux effects

Calcium efflux from the membranes of brain tissue in response to weak electromagnetic fields was first discovered by Bawin *et al*. (1975). It has since been repeated many times and also with other tissues such as frog heart muscle (Schwartz *et al*. 1990). The effects are strongest in the extremely low frequency range and in radio waves that have been amplitude modulated with extremely low frequencies). The phenomenon is curious in that it occurs only within "amplitude windows" with little or no effect at amplitudes above and below the window. However, the explanation is simple. Divalent positive ions such as calcium, because of their double charge, are more easily removed from the negatively charged membrane by weak alternating fields. If an alternating electrical field is applied across the membrane, the negatively charged membrane and the positively charged ions move in opposite directions so that the ions tend to bounce on and off the membrane. If the field is very weak, most of the ions remain stuck to the membrane. If it is very strong, they all bounce on and off more ore less equally but, somewhere in between, ions such as calcium with a double charge will be preferentially removed and replaced by less affected ions with a single charge such as potassium (potassium is the most likely ion to replace the calcium since it is by far the most abundant positive ion in living cells). This explains the amplitude windows for calcium release. 16Hz is particularly effective because it is the ion cyclotron resonance frequency for the potassium ion in the Earth's magnetic field. The potassium ion resonates at this frequency and acquires extra energy from the field, which makes it even more likely to replace the lost calcium. The whole process requires very little energy, since the ions are only moved by molecular dimensions. The effect is simply to change the chemical equilibrium between mono and divalent ions bound to the membrane and there is no theoretical minimum below which there is no effect, but the biological effects can be devastating.

Demodulation

In theory, umodulated radio waves should not release calcium from cell membranes because there is not enough time to replace the calcium with another ion before the field reverses. However, as shown by Bawin *et al.* (1975) calcium release does occur if the radio wave is modulated at a biologically-active low frequency, which suggests that living cells can demodulate it. The simplest way to demodulate a signal is to rectify it. Living cell membranes contain countless voltage-gated ion channels that open only when the voltage across the cell membrane reaches a pre-determined value. These can rectify low frequency signals but, because they require the mechanical opening and shutting of the channels, they cannot work at microwave frequencies. However, **any** ion channel, provided it is open, should be able to rectify, even at microwave frequencies, due to non-linearities imposed by the membrane potential. The membrane potential is a natural voltage of the order of 100mV across living cell membranes, which gives a voltage gradient of about 10 million volts per metre along each ion channel (which is about 10nm long). This voltage gradient gives the channel different electrical properties in either direction. In effect, the whole membrane behaves as an array of point contact Schottky diodes, which allows even microwave signals to be rectified and demodulated The extracted low frequencies appear across the membrane, where they can do most damage. This principle has been nicely illustrated by the construction of a complete radio set from a single carbon nanotube having a similar diameter to an ion channel.
(See http://tinyurl.com/m4u75o.)
When a voltage gradient was applied along the tube, it could both amplify and demodulate a radio signal, even at microwave frequencies.

Calcium loss weakens cell membranes

Calcium plays a vital role in strengthening cell membranes. Cell membranes are only about 10nm thick and consist mainly of a double layer of negatively charged phospholipids containing islands of protein that have various metabolic functions. Because most of these components are negatively charged, they tend to repel one another, but the membrane is stabilised by positive ions that sit in between them and function rather like the cement holding together the bricks in a wall. Calcium, with its double charge, is much better at doing this than ions with a single charge. When electromagnetic radiation replaces calcium ions with potassium, the membrane is weakened and becomes more likely to tear and develop temporary holes under the stresses and strain imposed by the continually moving cell contents (Steck *et al*. 1970, Lew *et al.* 1998, Ha 2001).

Consequences of leaky cell membranes.
Effects on metabolism

The concentration of calcium in the cytosol (the main part of living cells) is extremely low, usually much lower then that outside. If the external membrane leaks, free calcium enters the cell, where it has many effects on metabolism. At relatively low concentrations it may stimulate growth and repair (which may account for the apparent short-term beneficial effects of some electromagnetic fields) but at higher concentrations, it initiates several stress responses and growth is inhibited.

Cardiac arrhythmia

The heart muscle contracts in response to a wave of electrical activity passing through it, which is what we see in an electrocardiogram. This is generated by an ordered exchange of ions across its cell membranes. When these membranes leak as a result of electromagnetic exposure, this electrical wave becomes weakened and disordered, which can result in cardiac arrhythmia and a possible risk of a heart attack.

Effects on the skin

If cells leak some of their contents into the surrounding matrix, it will cause inflammation. This has frequently been associated with electromagnetic exposure.

Effects on the blood brain-barrier.

The brain is separated from the bloodstream by a barrier in which the gaps between the cells are normally sealed by “tight junctions”, which prevent unwanted materials entering the brain. Exposure to mobile phone radiation can breach this barrier to allow toxic materials such as albumin in the blood to enter, which can kill neurons (Salford *et al.* 2003) There is little immediate effect on brain function because the brain has spare capacity, but prolonged exposure will cause progressive brain damage and may be partly responsible for the current increase in early dementia and Alzheimer’s disease. This could be due to these materials leaking through perforated cell membranes or to an opening of the tight junctions themselves.

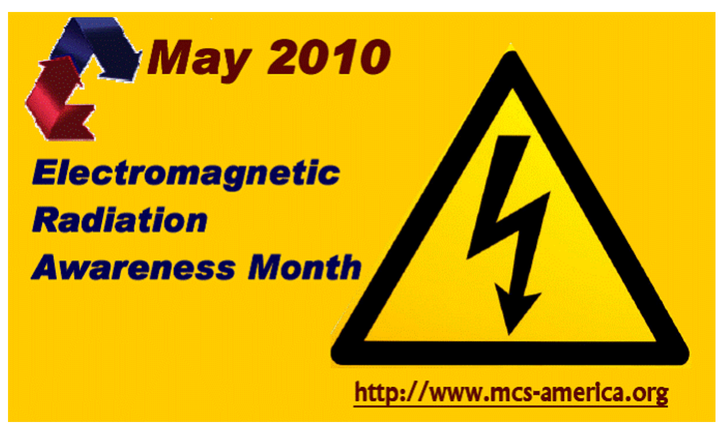
Effects on allergies

There are similar tight junction barriers protecting all of our body surfaces, including the skin (in the *stratum granulosum*) and the linings of the lungs, nose and gut. These normally stop foreign chemicals and allergens entering the body, but if electromagnetic radiation were to open these barriers too, it could explain the current increase in allergies, asthma and multiple chemical sensitivities. Calcium release is probably involved in these effects, since low external calcium or EGTA (a substance that removes calcium ions from surfaces) increase the permeability of respiratory epithelia to ions and particles as large as viruses(Chu *et al.* 2001).

Effects on nervous tissue.
Calcium regulates the activity of the nervous system. Information is normally passed from one neuron to another as chemical neurotransmitters that flow across the synapses where they make contact. Calcium is needed for these neurotransmitters to be released. A pulse of calcium normally enters the cytosol of the neuron, either from internal stores or from the outside, before each batch of neurotransmitter can be released. If their membranes leak as a result of electromagnetic exposure, unscheduled calcium enters, which increases its background concentration inside. This has an effect similar to a hair trigger so that, when the time comes to send a signal to its neighbour, the response is faster. This explains why weak electromagnetic fields can often shorten our reaction time to simple stimuli. The downside is that they can also trigger a spurious release of neurotransmitters that have no right to be there, causing brain hyperactivity and a reduced ability to concentrate. Both of these effects are often reported by people living near cell towers. Neuron hyperactivity of this sort has also been detected by electrodes placed into the brains of animals (Beason and Semm, 2002). It can be argued that the increasing prevalence of attention deficit hyperactivity disorder (ADHD) is due to this effect resulting from our ever increasing exposure to electromagnetic radiation.

Electromagnetic hypersensitivity (EHS)
An estimated three percent of the population suffer from some form of electromagnetic hypersensitivity, probably due to their sensory cells sending spurious signals to the brain when they are exposed to electromagnetic fields. They include false sensations of heat, touch (e.g. crawling sensations), pins and needles, pain, tinnitus, dizziness and nausea. These too can be explained in terms of membrane leakage. Although we have a wide variety of sensory cells scattered over our body, most of them function in the same way. Whenever they sense what they are supposed to sense, their external membranes leak ions, which reduces the natural voltage between their insides and outsides. This stimulates them to release neurotransmitters that trigger neighbouring nerve cells to send signals to the brain. When electromagnetic fields cause unscheduled leakage, false signals are sent, which can give a variety of false sensations, depending on which cells are most sensitive in the individual concerned. Many of these sensations are felt in the skin, but the hair cells of the inner ear can also be affected. Leakage in the hair cells of the cochlea give false sensations of sound (tinnitus) and those in the vestibular system (which sense rotation, linear acceleration and gravity) give false sensations of motion, which results in dizziness and symptoms of motion sickness, including nausea. The clincher is the effect on the eye. Unlike the rest of the sensory cells, the rods and cones of the retina actually **increase** their membrane potentials in response to light so that leakage here should **reduce** their response. This may be why electrosensitive people who have visual effects mostly report a partial loss of vision rather than seeing things that are not there.

What predisposes individual to electromagnetic hypersensitivity is unknown, but it could be because their cell membranes are already slightly leaky. This is supported by the findings of Eltiti *et al.* (2007) who found that the cells of individuals with EHS were more permeable to ions (as measured by skin conductance) than the control group ($p<0.001$)



DNA fragmentation

Many experiments have shown both single and double stranded DNA breakage in cell cultures after several hours of cell phone radiation (Lai and Singh 1995, Diem *et al*. 2005). Although DNA molecules are too stable to be damaged directly by non-ionising radiation, they can still be damaged indirectly as a result of enzyme leakage from lysosomes. Lysosomes are membrane bound structures in the cells of most higher organisms that normally digest waste for recycling. They contain many digestive enzymes, including DNase, which destroys DNA. Were these to leak as a consequence of electromagnetic exposure, we would expect to see DNA fragmentation and possible collateral damage to other cellular components. Cells that have been affected in this way may lose some of their normal function and also have an increased risk of becoming cancerous. A possible example of function loss is the effect of power line frequencies on the thyroid glands of rodents. Short-term exposure up to about three months boosted thyroid activity but longer exposures resulted in loss of function and a reduced ability make its hormones (Rajkovic *et al.* 2003). Long-term exposure would be expected to cause hypothyroidism, the main symptoms of which are fatigue, loss of muscle tone and obesity. The thyroid gland is in the neck, close to where you hold your cell phone and a large and increasing proportion of the population is becoming clinically obese. There is also some evidence of an increase in brain and other head cancers associated with cell phone use, but because of the long latency time of many cancers, we may not know the full effect of a potential outbreak for some years to come.

Effects on fertility

There have been many reports of reduced male fertility associated with heavy cell phone use and these have been recently reviewed by Desai *et al.* (2009). Exposure to the radiation leads to the production of fewer sperm, often with abnormalities, of which the most consistent is a loss of motility. Most of the effects seem to be due to membrane damage and the production of reactive oxygen species. In some cases, DNA damage has also been reported, which could lead to abnormalities in future generations. Most of the studies have been based on epidemiology since it is unethical to do controlled experiments on humans. Fortunately, it has proved possible to get similar effects on healthy donated sperm, where there is no ethical problem. Just 60 minutes exposure to GSM phone radiation (in talk mode) caused a significant reduction in the viability and motility of donated sperm compared with the unirradiated controls. This was associated with an increase in reactive oxygen species and free radicals, which could cause DNA damage, but no DNA damage was seen after this relatively short exposure (Agarwal *et al.* 2009).

The real value of this experiment as I see it is that it provides an excellent and relevant test-bed for evaluating the safety (or otherwise) of virtually all existing and proposed forms of wireless communications. Each test takes little more than a day or so to perform, does not require much in the way of sophisticated apparatus and, unlike experiments on tissue cultures, the results cannot easily be dismissed as irrelevant to the whole organism. The spermatozoa are in the germ line and encapsulate the whole future of the human race. Given the widespread use of cell phones, any damage that they do to the sperm threatens the whole human race. The human genome, which has taken countless millions of years to evolve, is now under very serious threat.

What can be done about it?

It is clear that we are not dealing with heating effects, so the ICNIRP guidelines are irrelevant. The damaging effect is almost certainly due to the way the microwave signal is modulated. The effects of the radiation on cryptochrome can be eradicated by removing the part of the lower sideband of the transmissions that overlaps with the cryptochrome frequencies.

Most of the remainder can be attributed to the apparent ability of living cells to demodulate the signal so as to extract biologically-active low frequencies. The challenge to the Industry is to develop methods of modulation that do not generate these frequencies or to make them invisible to living cells. This should not be too difficult since we have at our disposal many highly sophisticated modulation techniques, but the living cell has little more than the equivalent of a simple untuned diode to detect it. By paying careful attention to the way in which the signal is encoded, it should be possible to avoid having biologically active low frequencies. Another possibility is to transmit two mirror image signals on slightly different carrier frequencies. If living cells do not have the ability to distinguish between the two carrier frequencies, they will cancel each other out and the signal will appear to them as if it is unmodulated. Neither of these are beyond the wit of man, but until these problems are solved, no new wireless technologies should be rolled out and any existing products that fail the sperm test should be withdrawn as soon as possible.

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