Community Spotlight

Andrew Goldsworthy, PhD

Andrew Goldsworthy was born in 1939. After a conventional Grammar School education he obtained a First Class Honours 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, apart from a short time away, 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, remains as an honorary lecturer, and still gives occasional lectures on specialized subjects. He is also a scientific advisor to the European Space Agency and the h.e.s.e. project. He always had a strong interest in the way that 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 a simple layman's explanation of how weak electromagnetic fields affect us all. This can be found on the h.e.s.e.-project website at http://tinyurl.com/28lo82, which corresponds to http://www.hese-project.org/hese-uk/en/niemr/resonance1.php. He summarises much of it in this interview.

What are electromagnetic fields?

An electromagnetic field is a combination of an electrical and a magnetic field. An electrical field is what enables you to pick up small pieces of paper with a plastic comb after combing your hair on a dry day. A magnetic field is what lets you to pick up pieces of iron with a magnet. When an electric current flows through a wire it generates both kinds, so we call it an electromagnetic field. The electrical part depends on the voltage and the distance over which it is acting and is measured in volts per metre. The magnetic part depends on the current flowing and is measured in tesla. If you were to stand under a power line, you would be exposed to an electrical field corresponding to the difference in voltage between the line (which is set by the power company) and the ground. You would also be exposed to a magnetic field due to the current actually flowing, which depends on how much electricity people are using. Both kinds of field can produce biological effects, but the magnetic fields are generally considered to be more dangerous because they penetrate living tissues more easily.

Electromagnetic fields can be very useful because, when they change direction or strength; they can transmit energy. For example, the rapidly changing fields in the antenna of a radio transmitter transmit energy as electromagnetic waves at the speed of light to the antenna of a receiver. Here they generate a similar pattern of current-flow, which is amplified by the radio and converted to sound. Unfortunately, they also make similar currents flow in the human body and these can give a whole range of unwanted biological effects.

How prevalent is human exposure to electromagnetic fields?

They are very prevalent, for example, visible light and radiant heat from the sun are both electromagnetic waves that we have evolved to live with and are relatively harmless. Others with a much shorter wavelength such as X-rays and gamma rays can split molecules into fragments and ions. These are called ionizing radiations and everyone agrees that they can be harmful to life. But we now know that non-ionizing radiation with much longer wavelengths than light can also have biological effects. It was originally thought that this was because they heated the tissue, so safety guidelines were drawn up to limit our exposure to levels that caused no significant heating. But since then, many *non-thermal* effects have been discovered (see www.bioinitiative.org) where there seem to be direct electrical effects on the tissues at levels that may be hundreds of times below the official guidelines. However, the very existence of these non-thermal effects is hotly contested by the cell phone industry and even governments, possibly because they feel that they have a lot to lose if the general public were to discover that some of them were harmful. Unfortunately, most of us cannot escape this sort of radiation. It comes from overhead power lines, radio and television transmitters, domestic appliances and even the wiring in our own homes. But perhaps the most dangerous come from cell and cordless phones,

"I was too soft-hearted to do experiments on animals so I studied plants instead."

which we hold to our heads, and from their respective base stations.

What non-thermal biological effects have been observed in relation to weak non-ionizing electromagnetic fields? At what exposure level do these effects occur?

Effects that have been published in peer reviewed scientific journals include changes in the growth patterns of plants, changes in the rate of multiplication of yeast, the loss of calcium from animal cell membranes, the breakdown of the blood-brain barrier that normally prevents toxins from entering the brain, the destruction of DNA in human and animal cell cultures by cell phone radiation, reduced fertility in heavy cell phone users, increased incidence of cancer in people living near power lines, and various very unpleasant symptoms in people suffering from electromagnetic hypersensitivity. I can't give a precise figure for the levels of radiation at which these phenomena occur since there is considerable variation in the sensitivity of different individuals and even in the sensitivity of the different cell types in their bodies. However, to give you a rough idea of the range, effects have been reported for alternating electrical fields between one hundredth of a volt per metre and 10 volts per metre. The effects of alternating magnetic fields occur typically in and around the region of one millionth of a tesla, which is about one fiftieth of the Earth's steady magnetic field.

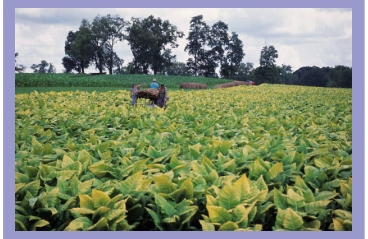
Why did you become interested in this topic?

First let me explain where I am coming from. My father was a ship's radio officer and I was an amateur radio enthusiast when I was a university student, so I am not a technophobe and you could even say that wireless is in my blood. But ever since I was a kid, I wanted to be a biologist to see how living things worked and what part electricity played in this. I was too soft-hearted to do experiments on animals so I studied plants instead. When I became a university lecturer, I initially researched in several different areas but ended up looking at the roles of electricity in plants.

What are these roles?

Electricity, which is carried by the flow of ions (electrically charged atoms and molecules) in living tissues, plays a major role in both animal and plant cells. There is quite an extensive and detailed amount of literature on this, but put very simply, energy is used to pump specific ions across cell membranes, which often generates a voltage (usually just a fraction of a volt) across them. They are then allowed back via a different route to complete the circuit, but as they go back, they can do some useful things. Hydrogen ions can generate ATP, which is a vital source of energy for the cell. Another important one is calcium. This is continuously pumped out of the main part of the cell but it is then let back in in carefully regulated amounts. The amount getting

"Effects of slowly alternating electromagnetic fields on metabolism have been found..."



back can then control the activity of many enzyme systems and genes. Also, small differences between the activity of the flow and return pathways at either end of the cell generates a voltage gradient along the cell's length that can control its speed and direction of growth. It follows that externally applied artificial currents, or treatments that made these membranes leak can cause quite significant effects on metabolism.

What are the effects on plants then?

Work on this has been going on for over a hundred years. As early as 1904 Karl Lemström published well-replicated studies showing increases in crop yield of up to 40 percent when cereals were grown under high voltage overhead wires. He attributed this to weak electric currents carried by air ions to the plants and, via the plants, to the soil. This work was continued in the 1920s by Vernon Blackman of Imperial College, who found that AC was more effective than DC and that growth was inhibited if the current was too strong. In particular, he discovered that after just a very short exposure, the growth rate of seedlings continued to increase long after the current was switched off. Nowadays, we might interpret this as meaning that the current had activated genes for growth, which then remained active.

I found similar results when weak electric currents (one millionth of an amp) were passed directly through plant tissue cultures. They not only grew faster but also showed a much greater tendency to regenerate into new plants. This also suggests that the effects were due to the activation of genes. But this too was inhibited if the current was too strong, suggesting that an overdose is harmful. Effects of slowly alternating electromagnetic fields on metabolism have been found not only in higher plants, but also in single celled microorganisms such as diatoms, where they affect their rate of locomotion, and yeast, where they affect the rate of cell division.

Relatively little has been published on the effects of radio frequency radiation on plants, but an often quoted example is pine trees around the Skrunda radar station in Latvia that showed severe growth inhibition (as measured by their annual rings) following the installation of the station. There was also evidence of additional stress (as measured by increased resin production) in trees having higher exposures to the radiation. All of these effects are non-thermal and are certainly not psychosomatic.

What made you turn your attention to animals?

From my own work on plants and yeast and the classic studies of Suzanne Bawin et al. on the electromagnetically-induced release of calcium from brain tissue, I guessed that at least some of the electromagnetic effects on plants were due to the loss of structurally important calcium ions from cell membranes. This made them leak and allowed *free* calcium ions into their cells, which affected

"What chance would I have of convincing others without my inside knowledge of the very real dangers of over exposure to electromagnetic pollution?"

the rate of metabolism, activated genes and changed the speed and pattern of growth.

To check on this, I looked more deeply at the literature on the effects of electromagnetic radiation on animals. I found that everything seemed to fit with my theories. The basic effects of weak electromagnetic fields on plants and animals were broadly similar and both could be explained by membrane leakage. It all fitted; it explained the changes in metabolism and gene expression found in animal tissue cultures and also the accelerations of healing following some electromagnetic therapies. But there was a darker side; it also explained the fragmentation of DNA, the loss of fertility, the rise in allergy-related conditions and the increased risk of cancer associated with prolonged electromagnetic exposure. All of these could also be due to membrane leakage. It was a eureka moment in reverse. Instead of feeling elated, I felt gutted. What were we doing to ourselves? Was our insatiable, but blind, love of electrical and electromagnetic gadgets slowly poisoning us all? It was like a bad dream and I felt I might wake up at any moment; but, that was not to be. I didn't want to believe them, but the scientific facts were staring me in the face. Having a logical explanation just made it worse.

So what could be done? If even I did not want to believe what was happening, what chance would I have of convincing others without my inside knowledge of the very real dangers of over exposure to electromagnetic pollution? Nevertheless, I had to try. I felt I could not live with myself if I did not publish my discoveries as widely as possible in a form that could be understood by the layman. I did it directly on the Internet rather than in specialist scientific journals, to which most people have no access. If anyone thought the ideas to be interesting, useful or relevant to a friend, they could be passed on at the click of a mouse and so spread naturally.

The main work can be found at http://tinyurl.com/28lo82 and in the links at the end of that article. They describe in simple terms how I think weak electromagnetic fields produce their non-thermal effects on cell membranes and they explain virtually all of the known biological responses to non-ionizing radiation, including those that are detrimental to health. They complement the excellent experimental work published in hundreds of papers in peer reviewed scientific journals, many of which have now been put in the public domain at www.bioinitiative.org. Taken together, they are a warning to us all.

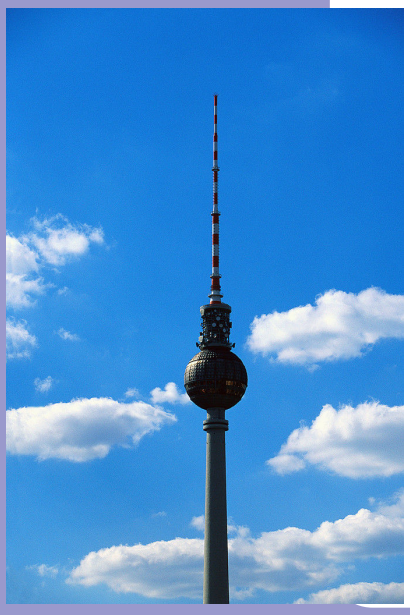
"This loss of calcium ions is important because it weakens the membranes."

What is the principal mechanism by which electromagnetic fields produce these non-thermal biological effects?

A good way to illustrate this is by analogy with an imaginary machine for harvesting ripe apples. It goes as follows:

John is proud of his machine for harvesting ripe apples. It works by shaking the tree with just the right force. If it is too weak, no apples fall off, if it is too strong, they all fall off, but if it is just right, only the ripe ones fall off and can be harvested.

If you can follow this, you will also be able to follow how weak electromagnetic fields can give biological effects without generating significant heat. They selectively "shake out" calcium ions from the delicate membranes that both surround living cells and divide them into compartments. These membranes are made mostly of negatively charged molecules interspersed with positively-charged ions that help to bind them together. Divalent ions (ions with two charges) such as calcium are better at binding than monovalent ions such as potassium, which have only one charge. Suzanne Bawin and her co-workers in 1975 showed that weak electromagnetic fields can selectively remove calcium ions from cell membranes, which we now know would reduce their stability. This work has been repeated in other laboratories and has been found to occur only with very weak radiation and is restricted to certain "windows" for field strength, above and below which there is little or no effect.

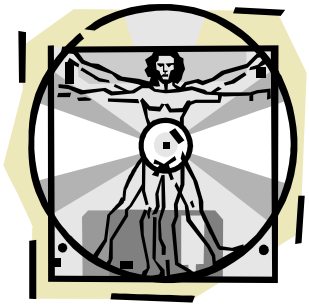


The explanation is simple if we remember John's apple harvester. The alternating electromagnetic fields "shake" the cell membranes, with the negatively-charged structural components and the positive binding ions moving in opposite directions. If the field is too weak, nothing happens. If it is too strong, all the ions are driven off and then back onto the membrane with each cycle. But if it is "just right" only the more strongly charged ions (such as divalent calcium) are affected and are selectively removed. Their place is then taken by less-affected monovalent ions such as potassium. This occurs mainly with low frequency alternating fields or radio-frequency fields that are amplitude-modulated or pulsed at a low frequency.

This loss of calcium ions is important because it weakens the membranes so that they are more likely to tear and develop temporary holes, especially when they are adjacent to moving cell contents. This can make them permeable even to large molecules such as enzymes. The leakage of digestive enzymes from lysosomes (membrane-bound particles that normally digest waste) into the rest of the cell is almost certainly responsible for the fragmentation of DNA in human and animal cell cultures seen after prolonged exposure to cell phone radiation. This genetic damage has been reported in several studies and is likely to cause cancer, a reduction in fertility (both of which are now becoming apparent) and possible mutations in future generations.

"There is no reason to believe that WiFi is any safer."

There is no reason to believe that WiFi is any safer. Although the signal is weaker, this does not necessarily mean it is safer. Because biological effects occur in specific "windows" for signal strength, there is no linear relationship between signal strength and physiological effects. If it fell within a window, a weaker signal could even be *more dangerous* than a stronger one. We must also remember that the router radiation is continuous, regardless of whether it is talking to a computer, so our exposure is chronic. This is serious because studies on mobile phone radiation show that the damage to DNA is dependent on the duration of the exposure and peaks in less than 24 hours.



Do our bodies have any defences against these electromagnetic onslaughts?

The human race, like other living organisms, has evolved some pretty good defence mechanisms to protect itself from *natural* non-ionizing radiation, but most of this, such as the "static" from thunderstorms, is weak and intermittent. One protection mechanism is the production of heat-shock proteins, which despite their name, can be triggered by electromagnetic radiation that is far too weak to generate significant heat. According to Martin Blank and his coworkers, they are produced by the direct activation of known base sequences in DNA. Their function is to combine with important proteins and enzymes in living cells to prevent them being destroyed by the digestive enzymes leaking from damaged lysosomes. Unfortunately, this also stops them working properly so that metabolic efficiency is reduced. It's rather like running a computer in "safe mode" when not all functions are available. This may be all right for as long as a thunderstorm normally lasts, but might be expected to give a more permanent and harmful reduction in metabolic efficiency with continuous exposure, e.g. from a cell tower or WiFi router.

In addition to the heat-shock proteins, there is an increased activity of the enzyme *ornithine decarboxylase*, which can be triggered by calcium leaking through damaged membranes. This enzyme is the starting point for a metabolic pathway leading to the production of *polyamines,* which protect DNA. However, these and other defence measures require metabolic energy and resources, which have to come from somewhere. They may be diverted from our physical energy so we have chronic symptoms of fatigue. They could also be diverted from the immune system, which would reduce our resistance to disease. In addition, these resources may not always be fully available, for example if we are ill. This could set up a vicious cycle in which illness increases our susceptibility to electromagnetic radiation, which in turn makes us more likely to be ill.

"Cell phone companies, as well as most governments, have a huge stake in mobile communication."

There are many things that governments could do if they put their minds to it. Probably the worst offenders are cell phones, digital cordless phones and Wifi. They should all carry government health warnings against prolonged use and WiFi (like smoking) should be banned in schools and public places until it can be proven unequivocally to be safe. There could be incentives to make us use these devices sparingly. For example, all cell phone tariffs other than pay-as-you-go could be withdrawn and increased rates charged for calls lasting over a few minutes. Hopefully, this would also reduce the number of cell phone base stations (cell towers) needed as well as the power that they radiate. These base stations are a major problem since, unlike cell phone handsets, they are in continuous operation and expose people living nearby to chronic biologically-active microwave radiation. Many people report suffering dizziness and other symptoms when exposed to the radiation from cell towers and there are anecdotal indications of clusters of cancer cases forming around them. It would therefore not be unreasonable to ask that they should not be located close to homes or places where people spend a great deal of their time. If this is not possible, the phone company should pay for adequate screening. The polluter should pay.

The electromagnetic safety of mains wiring could also be improved. Apart from not building houses near power lines, we should look at our domestic wiring. The trend to replace earthed metal conduit with plastic is a retrograde step. We should look in future to be using screened cable for domestic wiring and appliance cords. The trend to use un-earthed double insulated appliances should also be discouraged. While they offer little risk of electric shock, the lack of an earthed chassis makes them prone to emit stronger electromagnetic fields. Keep the double insulation by all means, but retain the earthed chassis.

How would you recommend approaching officials with this concern to bring about positive community change?

This is a difficult question since the cell phone companies, as well as most governments, have a huge stake in mobile communications and usually deny that there are any biological effects of radiation that is below their official safety guidelines (these are based only on heating effects). This is untrue and you can refer them to the wealth of information to the contrary that can be found at www.bioinitiative.org.
The fact is that the safety guidelines need to be revised in line with modern research.

A further point is that the costs of treating electromagnetically related illnesses such as MCS, allergies and reduced fertility, almost certainly exceeds the tax revenue from the cell phone industries (see http://tinyurl.com/32nu71) and may be expected to get worse as a predicted increase in cancer from DNA fragmentation becomes more apparent. In other words, the continued expansion in mobile communications using

"We must devise newer and safer methods of wireless communication as a matter of urgency."

present technology is already causing a net financial loss to the nation. On present trends, this is likely to get worse. We must devise newer and safer methods of wireless communication as a matter of urgency; and until this happens, the expansion and use of the present systems should be severely restricted.

Is there a way to reduce electromagnetic pollution without losing our access to cell phones, WiFi and other modern day technology?

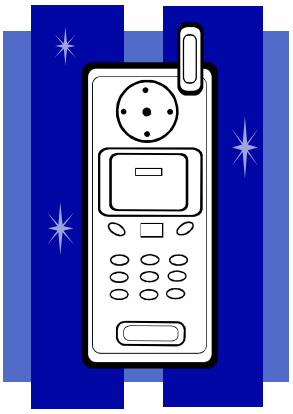
It is perfectly possible (although more expensive) to produce cell phones and base stations that work at lower power by using the latest low-noise technology and larger base-station antennae to collect weaker signals more efficiently. It may also be possible to encode the signals or use different frequencies so that the transmissions are less hazardous. How they do this is a matter for the engineers, but whatever the solutions, they should be tested for biological safety before going into production. The bottom line is that very few people would want to give up their cell phones entirely, and this may not even be necessary so long as they keep their phone calls short and relatively infrequent. However, the cell phone industry still has a duty of care not to poison us with their products and we should not be encouraged by advertising and offers of free airtime to make excessive use of them.

Is there anything that individual's can do on their own to protect themselves from electromagnetic pollution?

There is a great deal we can do ourselves to minimise our exposure.

Cell phones

Very few people would be willing to give up their cell phones; even I have one, although mine stays switched off and is only used in emergencies. If you have it switched on, even if you are not using it, it sends out regular signals at full power so that the phone company can keep track of where you are. If you must use one, use text messages, which need much less airtime, rather than voice calls. Any voice calls should be kept short, preferably to no more than a few minutes, and made from a good reception area; if reception is poor, the phone turns the power of its transmissions up to compensate. Do not use one in a car, even if you are not driving; reception inside its metal body is usually bad, so the phone will be transmitting at full power. Definitely do not use one while driving, not even a hands-free type, since the radiation from both sorts appears to interfere with normal brain function and makes you about four times more likely to have an accident.



"We should not use WiFi to connect our computers."

Cordless phones
Do not use digital cordless phones when it is possible to use a landline. I know they give you the freedom to wander around with them and still continue with the cooking, but they can be even more dangerous than cell phones. Although the handset is not as powerful as a cell phone and is completely inactive when not in use, the villain of the piece is the base station. This will be irradiating you with microwaves all day, every day, regardless of whether you are making a call. If you really must have a cordless phone, get a modern low radiation type such as the Orchid Low Radiation Phone, where the base station can be placed well away from the handsets, is only active when making a call, and the handset power is reduced when reception is good.

Cordless baby alarms
Be extremely careful in your choice of these since many of them work on the same principle as digital cordless phones and will be continuously irradiating your baby with pulsed microwaves. Not only could this be bad for the baby's health and development but, by interfering with melatonin production, it may even delay the onset of sleep.

WiFi
We should not use WiFi to connect our computers. Ethernet cables are not only safer but also much faster and more reliable. However, if you don't fancy drilling holes in walls or running patch leads under carpets, good alternatives are the various versions of "Homeplug". These send the

information from computer to computer in an encoded form via your normal mains wiring. The best ones are now as fast as Ethernet. If you are out and about, try to avoid WiFi hotspots such as WiFi-enabled restaurants, hotels etc. If sufficient people do this, the proprietors will soon get the message and switch it off.

Microwave cookers
Most of us in the developed world have one, but even the best of them leak at least some microwave radiation, so try not to get too close when they are in use.

Screening
Some people, such as those with electromagnetic hypersensitivity, suffer very badly. If moving to a less polluted area is not an option, they might consider screening their homes. This can be done with aluminium foil or an electrically conducting paint, together with electrically conducting net over the windows. More details of these can be found at www.powerwatch.org.uk
But don't forget, these measures will only protect you from external radiation. If you generate any inside, it could even make matters worse by reflecting it back at you.

"We have become heavily dependent on equipment that generates electromagnetic fields."

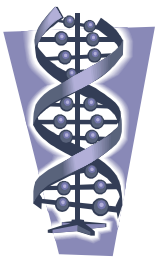
Electromagnetic exposure coupled to simultaneous illness is likely to be a major risk factor in developing cancer since it would leave our bodies even more poorly defended against electromagnetic radiation, and so increase the risk of DNA damage and all that ensues. After all, no one can guarantee that all of the trillions of cells in their bodies will be 100 percent healthy all of the time and very few genetically damaged cells may be needed to initiate a tumour. It seems likely that other electromagnetically induced conditions such as some forms of acquired EHS and MCS may also be triggered more easily by simultaneous illness. I know of at least one case where a perfectly healthy individual suffered a prolonged attack of ME, which was immediately followed by extreme electromagnetic hypersensitivity. Perhaps you may know of others. It might be a reasonable prediction that the longer the electromagnetic exposure and the longer the duration of illness the greater is the theoretical risk of doing permanent damage.

Where do allergies and MCS come into your thinking?

Apart from the damage to DNA and the consequent risk of cancer in future years, there is a much more immediate threat to the various "tight-junction barriers" that restrict the entry of foreign materials into our bodies. These barriers are layers of cells joined by impermeable substances (tight junctions) which prevent unwanted materials leaking in around their sides. They protect all of our body surfaces, including the skin, gut, lungs and respiratory tract. There is now very strong evidence that the increase in the permeability of cell membranes brought about by weak electromagnetic radiation allows some of these unwanted substances, including various allergens and a whole range of foreign chemicals, to enter the body by going straight through the cells and/or disrupting the tight junctions themselves. It seems likely that the present increase in allergies and allergy-related illnesses such as multiple chemical sensitivities, asthma, irritable bowel syndrome and even type-1 diabetes is due to our increasing exposure to electromagnetic fields. For more information and references, please visit http://tinyurl.com/32nu71

What steps would be necessary to protect individuals in the community from these effects?

We have become heavily dependent on equipment that generates electromagnetic fields and few of us would want to do without them. Think of it; no washing machines, no electric light, no automobiles, no cell phones, the list goes on. We cannot turn the clock all the way back without destroying our civilisation. All we can do is try to exploit as many as possible of our technological advances without unduly compromising our own health and safety.



"We are all in this together and we will all suffer if we get it wrong."

Where do we go from here?

For the time being there may be little we can do except to reduce our own personal exposure to non-ionizing radiation and keep up the pressure on governments to revise their official safety guidelines, which are at present far too lenient.

We should draw their attention, not just to the risk of cancer from excessive cell phone use (which may not become really apparent for several years) but to the loss of fertility and the rise in allergy-related illnesses that can now be linked to electromagnetic exposure. These are happening here; they are happening now and should be the subject of immediate and *independent* scientific investigation. In that the cost of these illnesses almost certainly exceeds the tax revenue from the cell phone industry, there may now be more of an incentive for them to do this.

Much of the necessary research could be just number crunching using existing data. Cell phone use, as determined from the phone company's records and living near cell towers could be correlated with the incidence of specific illnesses or allergies. This may be easier in countries such as the UK, which have state-run health services, where records may be more complete and less fragmented. In addition, simple and relatively benign experiments could be performed on animals to measure changes in skin permeability and the penetration of allergens in response to both acute and chronic electromagnetic exposure. Pigs might be a good choice since their size and subcutaneous fat makes them electrically similar to humans. No doubt, other people may have other suggestions. Hopefully, it should not take too long to establish the truth. Until we do, no one can be guaranteed to be safe, not even the bosses of the cell phone companies. We are all in this together and we will all suffer if we get it wrong.

-Andrew Goldsworthy