Making Mobile Phones Safer

Mobile phone radiation can be linked to colony collapse disorder and immune dysfunction
Bee colonies are dying mysteriously all over the developed world. Often their navigation systems fail and they do not return to the hive after collecting pollen and nectar, which can cause colony collapse disorder. Their immune systems also fail and they become unusually susceptible to pathogens to which they might otherwise be resistant. Both of these effects can now be linked by plausible mechanisms to the electromagnetic radiation from mobile telecommunications.

Why the bees are important.
If the decline of the bees continues, the effects on agriculture will be devastating and even the continued existence of the human race will be called into question. Many of our crops depend on bee pollination, and the remainder cannot provide a balanced diet. While the bulk of our staple foods come from wind-pollinated cereals that do not rely directly on the bees, these do not support the nitrogen-fixing bacteria needed for sustainable agriculture. Without bee pollinated crops (e.g. legumes) that host these bacteria, we will have to rely on artificial nitrogen fertilisers, which are either mined from limited natural sources or manufactured from the nitrogen of the air. Both are heavily dependent on fossil fuels and are not sustainable. Without them even our wind-pollinated crops will be decimated, which will lead to famine and mass starvation.

In addition, cereals do not provide an adequate balanced diet. In particular, they are almost totally lacking in vitamin C, which is essential to prevent scurvy. Scurvy is a fatal disease in which the body is unable to make the collagen needed for the connective tissue that binds our tissues and organs together. Without, it we literally begin to fall apart. The teeth fall out, the joints deteriorate and it leads to a slow and very painful death. Bee-pollinated crops are the main natural sources of vitamin C. Although some vitamin C producing species can self-pollinate or be propagated vegetatively, these are of necessity inbred and lack genetic diversity. Consequently, they will be less able to adapt to changing environmental conditions, including climate change and newly-evolved pathogens. They cannot be expected to last us for long.

Electromagnetic radiation is the most likely cause of bee loss
Whatever is causing the decline in the bee population in developed countries, it is likely to be man-made. Various possibilities have been mooted, including the varroa mite, pesticides and other agrichemicals, but the front runner, for which there is the most convincing evidence, is the radio-frequency radiation from mobile telecommunications. For example, German scientists placed cordless phone base stations (which emit modulated microwave radiation 24/7 just like mobile phone masts) next to some of their hives, but left others unexposed to the radiation. They then marked the bees as they left the hives and counted the proportion of the marked bees that returned. They found that a significantly larger proportion did not return in the hives that had been irradiated (more details at (http://tinyurl.com/rans84). But what could be the mechanism of this odd behaviour? It looks very much as if it is due to the effects on their *cryptochrome* pigments, which they use for both solar and magnetic navigation, and is highly sensitive to radio frequency radiation.

The Cryptochromes
The cryptochromes are a family of pigments found in virtually all animals and plants. The earliest forms (which we now call photolyase) absorb light and use its energy to repair damaged DNA. More recently evolved cryptochromes actually measure light and tell the organism whether it is night or day so that it can adapt its metabolism accordingly. Still later versions became an integral part of the "body clock", now present in virtually all animal and plant cells, which regulates the timing of their natural *circadian rhythms*. These rhythms regulate, amongst other things, our sleep-wake cycle and our resistance to disease. Normally, they are synchronised with day and night by environmental cues such as changes in light and temperature, but they can also run indefinitely under constant conditions (although they may not then be exactly 24 hours). They affect many aspects of metabolism and allow cells and organisms to *anticipate* the coming of dawn and dusk so that they can prepare themselves in advance for the new conditions. They are

extremely important for all of us; if they get out of kilter with the natural day-night sequence, such as when flying to a different time zone, we get jet lag and feel distinctly out of sorts until the rhythm become synchronised again.

Cryptochromes are used for animal navigation
Animals that use the sun for navigation have extremely accurate cryptochrome-based body clocks that enable them to compensate for its changing position throughout the day. Animals that navigate using the earth's magnetic field also use cryptochromes to sense the direction of the field. Cryptochrome can detect the direction of the field because it uses the energy of light to flip an electron between two parts of the molecule to generate a pair of unstable magnetic *free radicals*. The electron tries to return to its original position, but the rate at which it does so depends on the direction of the earth's field relative to the molecule, and gives an indication of the direction of the field. This sort of cryptochrome occurs in the eye and enables the animal to superimpose the direction of the magnetic field on its visual field as a "heads-up" display, which is ideal for navigation.

Electromagnetic fields disrupt cryptochrome-based magnetic navigation.
Thorsten Ritz and his co-workers (Nature, Vol. 429, pp177-180, 13th May 2004) showed that even weak electromagnetic radiation over a wide range of radio frequencies completely prevented robins orienting for navigation in a steady magnetic field simulating that of the Earth; the same is probably true for bees. The mechanism has since been confirmed and further elucidated by other workers. Although the active frequencies are lower than the nominal carrier frequencies used by mobile phones, they can be generated when they are modulated to carry information such as speech. Very little radio-frequency energy is needed since the energy to drive the process comes in this case from a high energy photon of light, which is stored in the free radical form of the molecule. The RF simply just modulates the thermodynamically downhill reaction that restores the status quo with a net **release** of energy. This allows non-ionizing radio frequency radiation, with photon energies far below that necessary to break chemical bonds, to give biological effects, which in this case disrupts magnetic navigation.

Solar navigation can also be affected.
The cryptochrome-based body clock in insects is also affected by magnetic fields, as was shown by Yoshii and coworkers in 2009 (more details at http://tinyurl.com/y9vkzfj); it is therefore likely that the bee's ability to navigate by the sun is also compromised.

The radiation from mobile phone masts and similar wireless devices can therefore disrupt bee navigation, both by the sun and by the earth's magnetic field. This can reduce the number of foraging bees returning to the hive and result in colony collapse disorder.

Effects on the immune system
Virtually all animal immune systems are under the control of their circadian rhythms. This is to make the best use of limited bodily resources, which are diverted from physical activity during the day to the immune system and the repair of damage at night. If these rhythms are disrupted, or their amplitude reduced by electromagnetic radiation, nothing they control can ever function at full power. Consequently, bees affected in this way may die, seemingly of other causes, including attack by pathogens to which they might otherwise be resistant. More information on circadian rhythms and their close links to the immune system can be found in Willard L. Koukkari and Robert B. Sothern. "*Introducing Biological Rhythms"*, pp 426 – 525. Springer 2006. ISBN 13: 078-1-4020-3691-0.

Effects on plants
The cryptochromes are one of several families of light-sensing pigments used by plants to control their patterns of growth and physiology so that they can make the best use of light for photosynthesis. For example, cryptochrome brings about the night time closure of stomata. Stomata are microscopic pores in the surface of leaves and stems used for photosynthetic gas

exchange. They open during the day to absorb carbon dioxide for photosynthesis and close at night to prevent the unnecessary loss of water vapour. Cryptochrome is also one of the pigments used to measure the length of the day to control photoperiodic responses; e.g. the deliberate shedding of leaves by deciduous trees in autumn is a response to short days.

There is mounting anecdotal evidence that radiation from mobile phone base stations disturbs these functions. I would like to invite you to see this for yourself. There is a very powerful Vodafone mast just outside the northeast corner of Hanger Hill Park, London W5, which appears to have damaged many of the nearby trees inside the park. Those in the main beam within a radius of about 400metres often show growth abnormalities with the younger shoots dieing. Many trees have actually died completely in the ten years or so that the mast has been operational. Most of them have now been removed, but there is still evidence of damage in those that remain. The cause of death also seems to be related to cryptochrome. Many of the mortalities occurred in dry conditions, possibly because the radiation kept the stomata open at night when they should have been closed. Another abnormality still visible in several trees is their partial or complete failure to shed their leaves and seeds in autumn; they remain dead on the tree but still firmly attached. It is as if the radiation absorbed by cryptochrome is perceived as light so that the tree behaves as if it was in continuous light and cannot respond to short days. This type of behaviour appears to have increased considerably since the power of the mast was increased to accommodate 3G.

A further effect of the radiation seems to be on the functioning of the plant equivalent of the immune system, which leads to attack by pathogens to which they would normally be resistant. This may explain the mysterious increase in general tree mortality from disease, especially bacterial diseases, in recent years. As in animals, cryptochrome plays a vital role in the regulation of the plant immune system. For example; recent work by Wu and Yang (Molecular Plant Advance Access Jan 6 2010, doi:10.1093/mp/ssp107) showed that *Arabidopsis* mutants lacking a functional cryptochrome 1 had a lowered resistance to the bacterial pathogen *Pseudomonas syringae*, whereas similar plants in which the gene was over expressed had enhanced resistance. If radio-frequency electromagnetic radiation were to compromise the normal functioning of cryptochrome, we might expect that this would reduce the plant's resistance to disease.

Effects on humans

Although humans have no natural ability for magnetic or solar navigation, we still use cryptochromes to control our circadian rhythms and immune systems. There are now increasing reports of cancer clusters around mobile phone masts that can be attributed to a failure of the immune system to dispose of incipient cancer cells. This is the most likely explanation since other factors that disturb our circadian rhythms, such as shift-working and exposure to continuous illumination, have similar effects on health. These include significant increases in the incidence of breast cancer, colorectal cancer and heart disorders (http://tinyurl.com/afgLjr). Similar increases are to be expected in people living close to mobile phone masts. Many of them already report poor sleep at night and tiredness during the day, which suggests that their natural circadian rhythms have been disturbed. Present evidence suggests that the radiation is perceived as light, which disrupts the dark phase of the cycle, during which the immune system should be most active. If so, humans who might normally tolerate the radiation during the day will be less able to do so at night. Every effort should therefore be made to avoid night time or continuous exposure to the radiation from base stations.

What can be done about it?

1. **Postpone any increase in power**. When you are in a hole, stop digging. The first thing to do is to suspend any increase in the power of mobile phone base stations until this problem has been solved.

2. **Use Femtocells**. This technology uses low power domestic base stations connected to the broadband network by a wired or optical links. It is already the preferred option for the mobile

phone operators (see http://www.ipaccess.com/femtocells/consumer_value.php) since it is cheaper, more reliable, and the consumer bears most of the cost. It also reduces the need for investment in high power base stations and reduces the traffic through each. If Femtocells lead to the bulk of the traffic being routed though these very low power base stations, which are partially shielded by the walls of the house, less will be routed through the major base stations and the effects on the bees and other wildlife should be minimised.

However, there are **some very important provisos**. The Femtocells **should be no more powerful than is necessary to cover a single household** and should **automatically cease transmission when not in use** (rather like an Orchid Low Radiation DECT Phone Base Station). This is not just to save electricity but also to minimise disruption of the circadian rhythms and immune systems of the users, their neighbours and wildlife. The fact that most of the Femtocells would then be inactive at night when the immune system would otherwise be most active is particularly important.

3. **Restrict the bandwidth of the signal**
A problem with digital signals is that their rapid rise and fall times generate a very large number of harmonics (multiples of the basic frequency). When these are used to modulate carrier waves, they generate very wide sidebands on either side of the carrier frequency, which actually carry the information. The width of each sideband corresponds to the frequency of the highest harmonic of the signal to be transmitted and is likely to overlap with the frequencies to which cryptochrome is sensitive. This "out-of-band" radiation does not normally interfere with other radio transmissions because it is relatively weak at any given frequency. However, cryptochrome is sensitive over a very wide range of frequencies and the signal is integrated over this range so that interference may be severe. A simple solution that should be investigated is to suppress the part of the lower sideband, which overlaps with the cryptochrome range. (This is already done with analogue television, which uses vestigial sideband transmissions). The upper base station sideband, and what remains of the lower one, will still contain all the digital information but should be relatively safe.

Other Modifications
While interference with cryptochrome is probably not the only way in which modulated radio waves from base stations give rise to biological effects, it is likely to be the one that has the most effect on the bees and also the immune systems and consequent risk of cancer in human beings. Other non-thermal biological effects of mobile phone radiation, such as DNA damage, have a different aetiology, but provided the immune system is fully functional, most of the damaged cells may be eradicated before they become cancerous.

Nevertheless, it may be possible to do something about this too. DNA damage is most likely due to the release of structurally-important calcium ions from cell membranes by modulated radio waves, first noted by Bawin *et al*. in 1975 (Effects of modulated VHF fields on the central nervous system. Ann NY Acad Sci 247: 74-81). There is strong evidence that this weakens the membranes and makes them more inclined to leak (A Goldsworthy in "Plant Electrophysiology: Theory and Methods" Ed AG Volkov. Springer 2006: ISBN-10 3-540-32717-7). When lysosomes leak, they release digestive enzymes, including DNase, into the main part of the cell to cause DNA fragmentation. Damage to the membranes of mitochondria will release free radicals that are normally used in the controlled oxidation of food products, but are kept locked up safely within the structure of the membrane. These free radicals can also damage DNA. However, it should be possible to modify the transmitted signal to avoid these effects on membranes too. This too may be easier than you think.

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