THE CELL PHONE AND THE CELL

Andrew Goldsworthy

Honorary Lecturer in Biology at Imperial College London.

Electromagnetic fields have effects at the cell level

Weak non-ionising radiation, such as that from mobile (cell) phones has biological effects, ranging from changes in brain function to the exacerbation of allergies and the induction and promotion of cancer. There have been many attempts to find the mechanisms and hundreds of scientific papers have been written about the changes they cause in the physiology and biochemistry of a wide range of living organisms (www.bioinitiative.org). These include plants, animals and even single cells such as yeast and diatoms. This means that least some of the effects must be occurring at the level of individual cells. There is more than one mechanism, but the one I will discuss here is the electromagnetic removal of calcium ions from cell membranes, which makes them become porous and leak. This simple observation can explain almost all of the known biological effects of weak electromagnetic radiation (Goldsworthy 2007).

Our bodies make good antennas

The biological effects of electromagnetic radiation probably begin with the organism acting like the antenna of a radio. The radiation generates eddy currents flowing through it and (in the case of cell cultures) also through the surrounding medium. When they impinge on the delicate membranes that surround its individual cells, they disturb their ionic structure and destabilise them. The same is true of the membranes that divide cells into their various internal compartments and organelles.

The human body makes a good antenna since blood vessels, which are low resistance pathways filled with a highly conductive salty fluid, connect virtually all of its parts. Even cell membranes, which have a high resistance to DC, allow radio-frequencies through because of their high capacitance. So when you use a mobile phone, its signal will be transmitted to all parts of your body; nowhere is safe.

Radiation increases membrane permeability

Many scientific studies suggest that the first effect of the eddy currents is to generate small alternating voltages across the cell membranes, which increase their permeability. This can have serious metabolic consequences as unwanted substances diffuse into and out of cells unhindered, and materials in different parts of the cell, that should be kept separate, become mixed. But how do these tiny alternating voltages increase membrane permeability?

The answer lies in their ability to remove calcium ions from the membrane surface. We have known since the work of Suzanne Bawin and her co-workers (Bawin *et al.* 1975) that electromagnetic radiation that is far too weak to cause significant heating can nevertheless remove radioactively labelled calcium ions from cell membranes. Later, Carl Blackman showed that this occurs only with weak radiation, and then only within one or more "*amplitude windows*", above and below which there is little or no effect (Blackman *et al.* 1982; Blackman 1990).

How weak fields remove calcium ions from membranes

Calcium ions are positively charged calcium atoms. Free calcium ions normally occur in calcium salts but, like other positive ions, they can also bind to the negatively charged membranes of living cells. These membrane-bound ions are in chemical equilibrium with the corresponding free ions in the surrounding medium, but there is a disproportionately large amount of calcium because it has two positive charges (i.e. it is *divalent*), which attracts it more strongly to the negative membrane. Most of the other readily available ions in living cells (e.g. potassium) have only one charge (i.e. they are *monovalent*). However, the extra charges on the divalent ions such as calcium and magnesium are literally their undoing. They let weak alternating electromagnetic fields remove them selectively from the membrane, which can have dire metabolic consequences.

The apple harvester

A simple way to explain the selective removal of divalent ions is to imagine trying to harvest ripe apples by shaking the tree. If you don't shake it hard enough, no apples fall off, but if you shake it too hard, they all fall off. However, if you get it just right, only the ripe ones fall off and are "selectively harvested".

We can apply the same logic to the positive ions bound to cell membranes. Alternating voltages try to drive these ions off and then back onto the membranes with each half cycle. If the voltage is too low, nothing happens. If it is too high, all the ions fly off, but return when the voltage reverses. However, if it is of just the right, it will tend to remove only the more strongly charged ones, such as divalent calcium with its double charge. Since at least some of these divalent ions will probably be replaced at random by other ions when the field reverses, there will be a net removal of divalent ions. However this occurs only within a narrow range of field strength to give an *amplitude window*.

There may be more than one window. Blackman discovered at least two for calcium removal from brain tissue. This may be because not all membranes are alike; for example, some may hold their calcium more firmly and need a stronger field to remove them. Also, the local availability of other ions to replace the calcium may affect the ease with which it is removed. Nevertheless, the general effect is that electromagnetic exposure within an amplitude window reduces the amount of calcium bound to the membrane.

Frequency effects

If they are to remove calcium in this way, the fields must be alternating. Low frequencies work best because they allow more time for dislodged calcium ions to diffuse clear of the cell membrane and be replaced by different ions, before the field reverses. Pulses are more effective than smooth sine waves because their rapid rise and fall times catapult the ions quickly away from the membrane and leave even more time for them to be replaced by different ions before the field reverses. This is probably why the pulsed radiation from mobile phones can be particularly damaging.

Radio waves

High frequency electromagnetic fields such as radio waves have relatively little biological effect unless they are *amplitude modulated* with a low biologically-active frequency. In amplitude modulation, the signal strength of the radio wave rises and falls in time with the low modulating frequency, but this has much the same effect in dislodging calcium ions as the raw low frequency.

Ion cyclotron resonance

Some low frequencies are unusually effective, either on their own or when used to modulate radio waves. This may be due to resonance. An example is 16Hz, which is the ion cyclotron resonance frequency of potassium ions in the Earths magnetic field.

Cyclotron resonance occurs when ions move in a steady magnetic field such as that of the Earth. They go into orbit around its lines of force at a characteristic frequency, which depends on the charge to mass ratio of the ion and the strength of the steady field (see Liboff *et al.* 1990). If they are simultaneously exposed to an alternating field at this frequency, they absorb its energy and increase the diameter of their orbits, which also increases their energy of motion and chemical activity.

Potassium resonance is particularly important because potassium is by far the most abundant positive ion in the cytosols of living cells, where it outnumbers calcium by about ten thousand to one. It is therefore the ion most likely to replace any calcium that has been lost by electromagnetic exposure. An increase in the chemical activity of potassium will therefore have a major impact on its ability to replace calcium. Consequently, calcium loss is enhanced at the resonant frequency for potassium. Also, any metabolic consequences of this calcium loss may be similarly enhanced. So if we discover bioelectromagnetic responses that peak or trough at 16Hz this is evidence that it may stem from divalent ion depletion in membranes.

In fact, many biological responses appear to peak at around the resonant frequency for potassium. These include stimulations of the growth of yeast (Mehedintu & Berg 1997) and higher plants (Smith et al. 1993), changes in rate of locomotion in diatoms (McLeod *et al.* 1987), and the especially severe neurophysiological symptoms reported by electrosensitive people exposed to the radiation from TETRA handsets (which is pulsed at 17.6Hz). All of this supports the notion that a large number of the biological responses to weak electromagnetic radiation stem from the loss of calcium (and possibly other divalent ions) from cell membranes.

Calcium removal makes cell membranes leak

Positive ions strengthen cell membranes because they help bind together the negatively-charged phospholipid molecules that form a large part of their structure.

Calcium ions are particularly good at this because their double positive charge enables them to bind more strongly to the surrounding negative phospholipids and hold them together like a cement. However, monovalent ions are less able to do this (Steck *et al.* 1970; Lew *et al.* 1998; Ha 2001). Therefore, when electromagnetic radiation replaces calcium with monovalent ions, it weakens the membrane and makes it more likely to tear and form pores, especially under the stresses and strains imposed by the moving cell contents. Normally, small pores in phospholipid membranes are self-healing (Melikov *et al.* 2001) but, while they remain open, the membrane will have a greater tendency to leak.

Metabolic consequences of membrane leakage

Membrane leakage can explain almost all of the adverse effects of electromagnetic radiation, including those from mobile phones and their base stations. I will describe just a few and explain how they can occur.

Mobile phone radiation can damage DNA

Lai and Singh (1995) were the first to show this in cultured rat brain cells, but it has since been confirmed by many other workers. The most comprehensive study on this was in the Reflex Project, sponsored by the European Commission and replicated in laboratories in several European countries. They found that radiation like that from GSM mobile phone handsets caused both single and double stranded breaks in the DNA of cultured human and animal cells. Not all cell types were equally affected and some, such as lymphocytes, seemed not to be affected at all (Reflex Report 2004). However, in susceptible cells, the degree of damage depended on the duration of the exposure. With human fibroblasts, it reached a maximum at around 16 hours (Diem *et al.* 2005).

Because of the very high stability of DNA molecules, they are unlikely to be damaged directly by weak radiation. The most plausible mechanism is that DNAase (an enzyme that destroys DNA), and possibly other digestive enzymes, were leaking through the membranes of lysosomes (organelles that digest waste) that had been damaged by the radiation. If so, there is also likely to be considerable collateral damage to other cellular systems.

If similar DNA fragmentation were to occur in the whole organism, we would expect a reduction in male fertility from damage to the DNA of developing sperm, an increased risk of cancer from DNA damage in other cells (this may take many years to appear) and genetic mutations that will appear in future generations. It would be unwise to assume that exposures of less than 16 hours are necessarily safe, since covert DNA damage could give genetically aberrant cells long before it becomes obvious under the microscope. It would also be unwise to assume that the damage would be restricted to the immediate vicinity of the handset since the signal is transmitted easily through the human body and only very weak fields are needed to give these non-thermal effects. Nowhere is safe, not even the sex organs.

Mobile phones can reduce fertility

We might expect DNA damage in the cells of the germ line to result in a loss of fertility. Several studies have shown significant reductions in sperm motility, viability and quantity in men using mobile phones for more than a few hours a day (Fejes *et al.* 2005; Agarwal *et al.* 2006; Agarwal *et al.* 2007), so it is advisable for men to keep their mobile calls to a minimum. We do not yet know the effects of mobile phone use on female fertility since the eggs are formed in the unborn foetus and we will have to wait until the child reaches puberty, to see the effects of her mother's mobile phone use.

So far, similar investigations have not been performed with the radiation from mobile phone base stations, but we cannot assume that they are necessarily safe just because they are further away. Radiation levels, even hundreds of metres from the mast, can still give biological effects and living near one will involve a considerably longer exposure than from just making the occasional phone call.

Radiation and allergies

The current massive increase in allergies and allergy-related illnesses can be attributed to our rising exposure to electromagnetic radiation. By increasing the permeability of the barriers that normally protect all of our body surfaces, it enhances the penetration of foreign chemicals and allergens and increases our sensitivity to them.

Electromagnetic exposure disrupts tight junction barriers

We might expect radiation that is strong enough to disrupt lysosomes also to be strong enough to disrupt the outer membranes of living cells so that these too become more permeable to large molecules. The effects of this would be most serious in the cells of the "tight-junction" barriers that protect many parts of our bodies. These normally give extra protection because the gaps between their cells are sealed with impermeable materials to restrict the passage of unwanted substances around their sides. An example is the blood-brain barrier, which normally prevents foreign materials in the bloodstream from entering the brain. The radiation from mobile phones can increase the permeability of this barrier, even to protein molecules as large as albumin (Persson *et al.* 1997) and this can damage the neurones beneath (Salford *et al.* 2003).

Calcium ions control barrier tightness

The loss in "tightness" of the blood-brain barrier could be due to an increase in membrane leakiness and/or to a disruption of the tight junctions themselves. Either of these could be triggered by an electromagnetically-induced loss of calcium. The central role of calcium in controlling the "tightness" of these layers is supported by an observation by Chu *et al.* (2001) on respiratory epithelia (which also have tight junctions). They found that either low levels of external calcium or the addition of EGTA (a substance that removes calcium ions from surfaces) caused massive increases in its electrical conductance (a measure of its permeability to ions) and to its permeability to much larger virus particles.

We have many tight junction barriers

One of these is the protective layer in the skin called the *stratum granulosum*, which is the outermost layer of *living* skin cells, where the cells are connected by tight junctions (Borgens *et al.* 1989; Furuse *et al*. 2002). In addition to this, virtually all of our other body surfaces are protected by cells with tight junctions, including the nasal mucosa (Hussar *et al.* 2002), the lungs (Weiss *et al.* 2003) and the lining of the gut (Arrieta *et al.* 2006). An electromagnetically-induced increase in the permeability of any of these would allow the more rapid entry into the body of a whole range of foreign materials, including allergens, toxins and carcinogens.

Loss of tightness can exacerbate many illnesses

Electromagnetically induced losses of barrier tightness at our body surfaces can explain how the general increase in public exposure to electromagnetic fields may be responsible for our ever-increasing susceptibility to various allergies, multiple chemical sensitivities, asthma, skin rashes and bowel cancer to name just a few. In addition, a non-specific increase in the permeability of the gut has been linked to type-1 diabetes, Crohns disease, celiac disease, multiple sclerosis, irritable bowel syndrome and a range of others (Arrieta *et al.* 2006). The list is truly horrendous and points to a very real need to reduce our exposure to non-ionising radiation.

Electrosensitivity

Electrosensitivity (alias electromagnetic hypersensitivity or EHS) is a condition in which some people experience a wide range of unpleasant symptoms when exposed to weak non-ionising radiation. Only a small proportion of the population is electrosensitive (currently estimated at around three percent) and an even smaller proportion is so badly affected that they can instantly tell whether a radiating device is switched on or off. At the other end of the scale, there are people who may be electrosensitive but do not know it, because they are chronically exposed to electromagnetic fields and accept their symptoms as being perfectly normal. Electrosensitivity is in fact a continuum and there is no clear cut-off point.

Causes and symptoms of electrosensitivity

Why some people are particularly susceptible to this condition is uncertain and not everyone shows the same symptoms. However, they seem to be characterised by having skins that have an unusually high electrical conductance (Eltiti *et al.* 2007, Table 5). This is consistent with them having a *stratum granulosum,* in their skins that is abnormally leaky, and may account for the high incidence of allergies and chemical sensitivities commonly found in this group.

One explanation for their sensitivity to the radiation is that they normally have low levels of calcium and/or magnesium in their blood. This gives low concentrations of these ions on their cell membranes, so that that less has to be removed by electromagnetic exposure to produce biological effects. The range of electromagnetically-induced symptoms reported by electrosensitives (which includes skin disorders, pins and needles, numbness, burning sensations, fatigue, muscle cramps, cardiac arrhythmia, and gastro-intestinal problems) is remarkably similar to those from hypocalcaemia (low blood calcium) (http://tinyurl.com/2dwwps) and hypomagnesaemia (low blood magnesium) (http://tinyurl.com/3ceevs). This suggests that they share a common aetiology, that being that there are inadequate concentrations of these divalent ions on the cell membranes to maintain stability. This promotes the formation of pores and gives rise to an unregulated flow of materials across them.

Ordinary people are affected too

Even people not suffering from EHS show changes in brain function in response to the radiation from mobile phones and their base stations. These include reacting more quickly to simple stimuli but having a poorer performance in more complex tasks (Abdel-Rassoul *et al.* 2007). Among the detrimental effects, is that on our ability to drive motor vehicles. According to the Royal Society for the Prevention of Accidents, we are four times more likely to have an accident while talking on a mobile phone, regardless of whether it is a hands-free type, whereas talking to a passenger has little or no effect.

All of this can be explained as a result of membrane leakage in neurones (highly branched brain cells, which behave like telephone exchanges that can transmit information to up to thousands of others). An essential part in the transmission of signals from one neurone to another is the release of calcium ions through membranes into the cytosol (the main part of the cell) in the transmitting neurone. This then triggers the secretion of chemical neurotransmitters that carry the signal to its neighbours via the synapses (where their branches make close contact). Because electromagnetically induced membrane leakage will give a higher background concentration of calcium in the cytosol, the neurones will respond sooner to stimulation and give a faster reaction time for the whole organism.

However, they will also be more likely to generate spurious nerve impulses that reduce the signal to noise ratio of the brain and create a mental fog. This will make weaker signals less discernible and result in more errors when performing complex tasks such as driving car. This can be thought of as a special case of electromagnetically-induced Attention Deficit Hyperactivity Syndrome (ADHS).

Autism

There has been a 6000 percent increase in autism in recent years, which corresponds in time to the proliferation of mobile telecommunications, Wifi and microwave ovens. We can also explain this in terms of electromagnetically-induced membrane leakage leading to brain hyperactivity.

Just after its birth, a child's brain is essentially a blank canvas, and it goes through an intense period of learning to become aware of the significance of all of its new sensory inputs, e.g. to recognise its mother's face, her expressions and eventually

other people and their relationship to him (Hawley & Gunner 2000). During this process, the neurones in the brain make countless new connections, the patterns of which store what the child has learnt. However, after a matter of months, connections that are rarely used are pruned automatically (Huttenlocher & Dabholkar 1997) so that those that remain are hard-wired into the child's psyche. The electromagnetic production of spurious action potentials during this period will generate frequent random connections, which will also not be pruned, even though they may not make sense. It may be significant that autistic children tend to have slightly larger heads, possibly to accommodate unpruned neurones (Hill & Frith 2003).
Because the pruning process in electromagnetically-exposed children may be more random, it could leave the child with a defective hard-wired mind-set for social interactions, which may then contribute to the various autistic spectrum disorders. These children are not necessarily unintelligent; they may even have more brain cells than the rest of us, and some may actually be savants. They may just be held back from having a normal life by a deficiency in the dedicated hard-wired neural networks needed for efficient communication with others.

A useful homology might be in the socialisation of dogs. If puppies do not meet and interact with other dogs within the first four months of their life, they too develop autistic behaviour. They become withdrawn, afraid of other dogs and strangers, and are incapable of normal "pack" behaviour. Once this four-month window has passed, the effect seems to be irreversible (just like autism). If this homology is correct, it suggests that experiments on dogs could hold the key to the investigation of autism and its possible links with electromagnetic exposure.

Defence mechanisms

The body is well able to detect weak non-ionising radiation and the resulting damage. This ability probably evolved over countless millions of years to mitigate the effects of the wideband radiation from lightning during thunderstorms. We already know how some of them work. These are as follows.

Calcium expulsion.

The concentration of free calcium in the cytosols of living cells is normally kept extremely low by metabolically-driven ion pumps in the cell membrane. Under normal circumstances, the entry of free calcium ions is carefully regulated and small changes in their concentration play a vital role in controlling many aspects of metabolism. These processes can be disrupted if electromagnetically-induced membrane leakage lets extra and unscheduled amounts of calcium into the cell, either from the outside or from calcium stores inside. To compensate for this, the mechanism that normally pumps surplus calcium out can go into overdrive. However, its capacity to do this is limited because, if the pumping were too effective, it would hide the small changes in calcium concentration that normally control metabolism.

Ornithine decarboxylase (ODC)

The activation of the enzyme *ornithine decarboxylase* is triggered by calcium leaking into cells through damaged membranes and by nitric oxide produced by damaged mitochondria (membrane-bound particles that provide most of a cell's energy). This enzyme leads to the production of chemicals called *polyamines* that help protect DNA, and the other nucleic acids needed for protein synthesis.

Heat-shock proteins

These are perhaps wrongly named because they can also be produced directly in response to *electromagnetic radiation* at levels millions of times lower than those that generate significant heat (Blank & Goodman 2000). We even know the base sequence of the DNA that senses the radiation. The job of these heat-shock proteins is to combine with vital enzymes, putting them into a sort of cocoon that protects them from damage. However, this also stops them working properly, so it isn't an ideal solution.

As we can see, these defence mechanisms are triggered either by radiation-damage or by the radiation itself. Their role is to try to limit the damage, but they cannot be deployed without using extra energy and disrupting the cell's normal functions. Consequently, they are programmed not to cut in until the damage approaches intolerable levels. This effect will maintain the damage and observable symptoms close to the levels at which they cut in over a wide range of radiation intensities. Consequently, electrosensitive individuals may find that their symptoms (such as headaches and dizziness) from distant mobile phone masts and local handsets may be approximately the same, at least in the short term.

Long-term effects

These defence mechanisms originally evolved to protect living organisms from weak natural radiation, such as that from thunderstorms. However, they were "designed" only for intermittent use because they disrupt normal metabolism and are expensive in bodily resources and energy. These resources have to come from somewhere. Some may be drawn from our physical energy, making us feel tired. Some may come from our immune system, making us less resistant to disease and cancer. There is no hidden reserve. As it is, our bodies are constantly juggling resources to put them to best use. For example, during the day, they are directed towards physical activity but during the night, they are diverted to the repair of accumulated damage and to the immune system. Day and night irradiation from mobile phone masts (which run continuously) will affect both, with little or no chance to recover. In the long term, this is likely to cause chronic fatigue, serious immune dysfunction (leading to an increased risk of disease and cancer) and many of the neurological symptoms frequently reported by people living close to mobile phone base stations (see Abdel-Rassoul *et al.* 2007).

DECT phones and Wifi may be just as bad

There is a growing number of anecdotal reports that the continuous radiation from DECT phone base stations and Wifi routers can have similar effects to mobile phone base stations; so these too should be considered as potentially unsafe. We should perhaps add to these the growing use of DECT cordless baby alarms. Although to date there is no firm evidence of adverse effects, these devices irradiate the baby continuously at close range and, to the best of my knowledge, they have not been tested for electromagnetic safety. It is ironic that any proposal to test them with real children would probably be turned down as being unethical. Nevertheless, they are on the market and the exposed child will probably be too young to report any symptoms. One symptom to look for would be a delay in the onset of sleep due to brain hyperactivity; this could be an early warning of potential damage that may not become apparent until later life. Bearing in mind a possible link between electromagnetic exposure during early childhood and autism, it might be a wise precaution to stick to the old-fashioned wired baby alarm.

Why we are not all affected

This is due to natural biological variability and is quite normal. For example, not everyone who smokes dies of cancer; it just increases the risk. Similarly, not everyone will be equally affected by non-ionising radiation. There could be many reasons for this; some people may have higher levels of calcium in their blood, which will help stabilise their cell membranes. Others may have more effective natural defence mechanisms or mechanisms that cut in at different levels. Still other people may have had their defence systems impaired, either by illness or prolonged electromagnetic exposure. Many more may actually be affected but have just put it down to the general stress of modern living and have not yet made the link between their symptoms and our now almost universal electromagnetic exposure.

However, even if you are one of the lucky ones who suffer no obvious short-term adverse effects from electromagnetic radiation, there is no cause for complacency. There is no guarantee that you will not suffer long-term effects or that the apparent lack of effect will continue as the general levels of electromagnetic exposure rise and our steadily aging bodies become less and less able to cope. In many ways, the effects of electromagnetic exposure may resemble those of premature aging.

What can we do about it?

Very few people would want to give up their mobile phones, but if you have one, for your own personal safety, it is best to keep your calls on it short and relatively infrequent so that your body has a chance to recover in between times. Use text (which takes seconds to transmit) rather than voice calls and avoid making unnecessary downloads from the Internet. The choice is yours, but spare a thought for the people living near the base stations. Some of them may be badly affected by their continuous irradiation but they have no choice. Your mobile calls will contribute to their problems, so your restraint may help them too.

Dangerous water towers

There is a growing tendency to mount mobile phone base station antennas on water towers. This may seem convenient, but it carries a hidden risk because the radiation may also affect the water to make it *biologically active*.

Weak pulsed radiation is routinely used in "electronic" water conditioners to remove lime scale from plumbing. The mechanism of the conditioning effect is still controversial but it depends on the presence of impurities and does not work with all water supplies. It appears to involve changes in the pattern of ions bound to colloids, which alter their surface charge and make them more attractive to calcium ions.

However, the treated water has biological effects similar to those from exposure to weak electromagnetic radiation, perhaps due to its removing calcium ions from cell membranes, just as it removes lime scale from water pipes and boilers.

Laboratory experiments with yeast cultured in electromagnetically conditioned water showed that its biological effects depended on the length of time for which the water was conditioned. In our hands, treating London tap water for 30 seconds or less (as it would be when passing through a domestic water conditioner) resulted in its stimulating cell division in yeast but caused no obvious harm. However, treatment for longer than this (as it would be if a water storage tank were to be irradiated) inhibited cell division, suggesting that it may now be toxic (Goldsworthy *et al.* 1999).

If a similar effect were to occur in water towers fitted with mobile phone antennas, it could have adverse effects on public health. Because the conditioning effect on water can last up to several days, this gives ample time for it to be distributed widely through the water mains and so present an even greater threat to the public than the antennas themselves. This needs urgent attention by the water companies since, unlike the mobile phone operators, they have no legal immunity from prosecution for distributing a potentially toxic product.

Postscript

At present, legislation by many governments (presumably at the request of the mobile phone operators) prevents anyone objecting to the location of base stations on health grounds, and governments have been advised not to recognise the problem. I hope that this article may go some way to achieving this much-needed recognition. The problem is far more serious than anyone has previously imagined. The effects on people with EHS and allergy-related conditions are bad enough in their own right but, with about half the world's population already owning a mobile phone, the resulting widespread genetic damage threatens the future of the entire human race.

References

Abdel-Rassoul G, Abou El-Fateh O, Abou Salem M, Michael A, Farahat F, El-Batanouny M, Salem E (2007), Neurobehavioral effects among inhabitants around mobile phone base stations. Neurotoxicology 28 434-440

Agarwal A, Prabakaran SA, Ranga G, Sundaram AT, Shama RK, Sikka SC (2006), Relationship between cell phone use and human fertility: an observational study. Fertility and Sterility 86 (3) Supplement 1 S283. Data also available at http://tinyurl.com/28rm6n

Agarwal A, Deepinder F, Rakesh K, Sharma RK, Ranga G, Li J (2007), Effect of cell phone usage on semen analysis in men attending infertility clinic: an observational study. Fertility and Sterility. In Press (available on line - doi:10.1016/j.fertnstert.2007.01.166)

Arrieta MC, Bistritz L, Meddings JB (2006), Alterations in intestinal permeability. Gut 55: 1512-1520

Bawin SM, Kaczmarek KL, Adey WR (1975), Effects of modulated VHF fields on the central nervous system. Ann NY Acad Sci 247: 74-81

Blackman CF (1990), ELF effects on calcium homeostasis. In: Wilson BW, Stevens RG, Anderson LE (eds) Extremely Low Frequency Electromagnetic Fields: the Question of Cancer. Battelle Press, Columbus, Ohio, pp 189-208

Blackman CF, Benane SG, Kinney LS, House DE, Joines WT (1982), Effects of ELF fields on calcium-ion efflux from brain tissue in vitro. Radiation Research 92: 510-520

Blank, M, Goodman R (2000), Stimulation of stress response by low frequency electromagnetic fields: possibility of direct interaction with DNA. IEEE Trans Plasma Sci **28** 168-172

Borgens RB, Robinson, KR, Vanable JW, McGinnis ME (1989), Electric Fields in Vertebrate Repair. Liss, New York

Chu Q, George ST, Lukason M, Cheng SH, Scheule RK, Eastman SJ (2001) EGTA enhancement of adenovirus-mediated gene transfer to mouse tracheal epithelium in vivo. Human Gene Therapy 12: 455-467

Diem E, Schwarz C, Adlkofer F, Jahn O, Rudiger H (2005), Non-thermal DNA breakage by mobile phone radiation (1800 MHz) in human fibroblasts and in transformed GFSH-R17 rat granulosa cells in vitro. Mutation Research / Genetic Toxicology and Environmental Mutagenesis 583: 178-183

Eltiti S, Wallace D, Ridgewell A, Zougkou K, Russo R, Sepulveda F, Mirshekar-Syahkal D, Rasor P, Deeble R, Fox E (2007), Does short-term exposure to mobile phone base station signals increase symptoms in individuals who report sensitivity to electromagnetic fields? A double blind provocation study. http://tinyurl.com/39ddyv

Fejes I, Zavaczki Z, Szollosi J, Koloszar S, Daru J, Kovaks L, Pal A (2005), Is there a relationship between cell phone use and semen quality? Arch Andrology 51: 385-393

Furuse M, Hata M, Furuse K, Yoshida Y, Haratake A, Sugitani Y, Noda T, Kubo A, Tsukita S (2002), Claudin-based tight junctions are crucial for the mammalian epidermal barrier: a lesson from claudin-1- deficient mice. J Cell Biol 156; 1099-1111

Goldsworthy A (2007), The biological effects of weak electromagnetic fields. http://tinyurl.com/2nfujj

Goldsworthy A, Whitney H, Morris E (1999), Biological effects of physically conditioned water. Water Research **33** 1618-1626

Ha B-Y (2001), Stabilization and destabilization of cell membranes by multivalent ions. Phys Rev E 64: 051902 (5 pages)

Hawley T, Gunner M (2000), How early experiences affect brain development. http://tinyurl.com/5u23ae

Hill EL, Frith U (2003), Understanding autism: insights from mind and brain. Phil Trans R Soc Lond B **358** 281-289

Hussar P, Tserentsoodol N, Koyama H, Yokoo-Sugawara M, Matsuzaki T, Takami S, Takata K (2002), The glucose transporter GLUT1 and the tight junction protein occludin in nasal olfactory mucosa. Chem Senses 27: 2-11

Huttenlocher PR, Dabholkar AS (1997) Regional differences in synaptogenesis in human cerebral cortex. J Comparative Neurology **387** 167-178

Lew VL, Hockaday A, Freeman CJ, Bookchin RM (1988), Mechanism of spontaneous inside-out vesiculation of red cell membranes. J Cell Biol 106: 1893-1901

Lai H, Singh NP (1995), Acute low-intensity microwave exposure increases DNA single-strand breaks in rat brain cells. Bioelectromagnetics 16: 207-210

Melikov KC, Frolov VA, Shcherbakov A, Samsonov AV, Chizmadzhev YA, Chernomordik LV (2001), Voltage-induced nonconductive pre-pores and metastable single pores in unmodified planar lipid bilayer. Biophys J 80: 1829-1836

Persson BRR, Salford LG, Brun A (1997), Blood-brain barrier permeability in rats exposed to electromagnetic fields used in wireless communication. Wireless Networks 3: 455–461

Reflex Report (2004), http://tinyurl.com/cf3q4

Salford LG, Brun AE, Eberhardt JL, Malmgren K, Persson BRR (2003), Nerve cell damage in mammalian brain after exposure to microwaves from GSM mobile phones. Environmental Health Perspectives 111: 881-883

Steck TL, Weinstein RS, Straus, JH, Wallach DFH (1970), Inside-out red cell membrane vesicles: preparation and purification. Science 168: 255-257

Weiss DJ, Beckett T, Bonneau L, Young J, Kolls JK, Wang G (2003), Transient increase in lung epithelial tight junction permeability: an additional mechanism for of enhancement of lung transgene expression by perfluorochemical liquids. Molecular Therapy 8: 927-935