

## Mobile Phones

The Mobile Phones set of articles is separated into 9 sections, each of which can be individually downloaded. It is a 'work in progress' incorporating new information whenever time permits.

### Section 5 Biological control systems, DNA changes and effects on cells and the blood

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## Biological control systems, DNA changes and effects on cells and the blood

The premise of *"If it doesn't heat you, it won't hurt you"* has been the only guideline for EMF exposure for some decades. This has been called into question for about the same length of time, and many scientists and biologists now believe that the guidelines based on this are inadequate to protect us against RF radiation. Iakimenko (2011), in a review of biological effects of RF says *"Among the reproducible effects of low-level microwave radiation are overexpression of heat shock proteins, an increase of reactive oxygen species level, an increase of intracellular Ca<sup>2+</sup>, damage of DNA, inhibition of DNA reparation and induction of apoptosis."*

Out of the 1,500 studies (July 2009), on health-related effects of RF radiation, 70% found significant effects.

Many leading EMF-bio-effects scientists believe living systems use electromagnetic fields to convey information needed for survival. This includes the replication of DNA, the function of the immune system, relaying of messages to the brain and communication. As long ago as 1982, the late Professor Adey, one of the foremost researchers into the biological mechanisms underlying EMF interaction with human cells, said *"It is now well established that intrinsic electromagnetic fields play a key role in a broad range of tissue functions, including embryonic morphogenesis, wound healing, and information transmission in the nervous system. These same processes may be profoundly influenced by electromagnetic fields induced by an external force."*

An interesting study by Rossi (2011) showed how cells in one petri dish affected cell proliferation rate and morphology of the cells in another petri dish even when separated, an example of the bystander effect. A black filter prevented transmission of electromagnetic radiation between 2 other petri dishes and no changes were observed. The study authors assumed that there was some form of intercellular electromagnetic communication causing the changes in the affected cells.

A study by Marková (2010) concluded that the strongest microwave effects were always observed in stem cells and they reacted to more frequencies than do differentiated cells. Shahbazi-Gahrouei (2016) found that the 900 MHz RF signal radiation from a mobile phone antenna can reduce cell viability and proliferation rates of human adipose-derived stem cells depending on the duration of exposure.

The Austrian Insurance company AUVA report in 2009 verified that EMFs from mobile phones damage the brain and nervous system, immune system, and induced changes in protein synthesis which led to increased rates of DNA breakage, starting at 0.1 W/kg, 20 times lower than the UK safety guidelines (AUVA report: *Nonthermal effects confirmed; exposure limits challenged; precaution demanded*. August 22 2009 from <http://www.diagnose-funk.org>).

Garlic was found to be an antioxidant preventing adverse protein changes in brain metabolism, if administered at the same time as exposure to 1.8 GHz RF radiation (Avci 2012). Exposure to mobile phone radiation caused a significant increase in nitric oxide (NO) in the serum and oxidative stress changes in brain tissue, which garlic offered some protection from (Bilgici 2013).

### Biological control systems

Mobile phones are known to heat body tissue (the temperature of ears during a call can increase by over 0.5°C). Many people complain of heating of the ear, head or neck as one of the side effects of phone use. An analogue phone caused an increase in temperature of 4.5°C and a 2G phone 2.3°C in the user's cheek after 6 minutes use in one study (Anderson & Rowley 2007). The authors

suggested that RF radiation was responsible for only a part of the heating effect, the rest was due to heat conduction from the batteries (Tahvanainen [2007](#)). Paredi ([2001](#)) reported that mobile phone use heats the head, including the blood, so that it cannot manage to keep the brain as cool as it should be. Microwaves may increase skin temperature and therefore cause vasodilation.

A study in Australia showed that the thyroid, pancreas, ovaries, testes and hormonal balance were affected, as measured by blood tests, after using a mobile phone for 10 minutes on two consecutive days. The tests showed that the endocrine system of volunteers was severely impacted by using the mobile phone for just 10 minutes. While all volunteers showed hormonal changes, most showed stress to the pancreas, some to the ovaries or testes, some showed inflammation and a few showed thyroid impacts. Two studies by Söderqvist ([2009](#), [2009](#)) have shown changes in transthyretin after mobile phone exposure, a potential breach of the blood-cerebrospinal fluid barrier. Those whose thyroids were most affected showed greatest stress to the phone exposure, with one subject totally exhausted and unable to move for some time after each exposure. RF exposure from mobile phones has been found to cause pathological changes in the thyroid gland by altering the gland structure and increasing cell death (Esmekaya [2010](#)). According to Jennie Burke, Director of Australian Biologics, the profound impacts on the endocrine system that she detected are likely to be due to hormonal changes in the hypothalamus or the pituitary gland.

RF radiation changed cells in the immune system, with a dose response relationship (Zhou [2008](#)). Significant transcriptional effects were observed after long-term RF-EMF exposure on immune-like T cell populations (Ohtani [2015](#)).

Noor ([2011](#)) found changes in excitatory and inhibitory amino acids in rat brains after RF exposure. The authors believe that these alterations may underlie the adverse effects of using mobile phones.

Kesari ([2011](#)) found a reduction in some, and an increase in other, antioxidative enzyme activities (Jelodar [2013](#)), as well as protein kinase C, melatonin, caspase 3, and creatine kinase related to overproduction of ROS in animals under mobile phone radiation exposure. The review (Kesari [2013](#)) concluded that the regular and long-term use of phones can have a negative impact on the brain. The authors also suggested that the attendant increased ROS may cause neurodegenerative diseases.

Kwon ([2011](#)) found that short-term mobile phone exposure locally suppressed brain energy metabolism in humans.

Mobile phone RF emissions damaged the developing neurons in chick dorsal root ganglia that was dose dependent and persisted (Ingole & Ghosh [2012](#)).

## Heat shock protein

Biologist and geneticist Dr David de Pomerai, at Nottingham University, showed exposure to radiation from mobile phones for an hour could double heat shock protein (HSP) in cells ([2000](#)). Even half an hour after exposure, cells behaved *as if* they were heated by 3°C, although there was no actual rise in temperature. Dr de Pomerai said in the journal *Nature*, "If that reaction is left unchecked it would 'gum up' the cell with protein and it would become lethal to that cell." Velizarov ([1999](#)), Harvey & French ([2000](#)), Kwee ([2001](#)) and Chauhan ([2007](#)) found similar cellular changes at temperatures below heating levels. Valbonesi ([2014](#)) found that HSP70 expression, observed only in cells exposed to the GSM-217Hz signal, is a repeatable response previously reported in human trophoblast cells and now confirmed in PC12 cells. The authors suggested that "Further investigations towards a possible role of 1.8 GHz signal modulation are therefore advisable". Dr French

says "if you turn on the heat shock protein response all the time, that can cause the cells to become cancerous. It is also an inducer of metastasis, or cancer spread." Professor Gordon McVie, director of the Cancer Research Campaign, said "If the cells were exposed to heat shock over a long time it might exhaust the repair process. This may produce mutations and that is where you get problems. It takes more than one mutation to cause cancer, but it is very much a slippery slope." De Pomerai later found no effect (Dawe [2008](#)), neither did Sanchez ([2007](#)) find heat shock protein changes in rat skin as a result of GSM signals.

Markova ([2005](#)) found effects on human lymphocytes, similar to heat shock. It was dependent on carrier frequency.

Barrie Trower, a UK expert on Electrical Sensitivity (ES), says that a rise of just 0.6°C can cause heat shock proteins to take various measures to start protecting cells from microwave induced heat. If they leave one vital task to start defending cells against internal hotspots, we may not have the resources to protect our immune system, or to repair pre-cancerous cells.

Lee's study ([2005](#)) found that 221 genes altered their expression after a 2 hour exposure to RF, and 759 after a 6 hour exposure. There was no significant increase in the expression of heat shock genes, showing that the mechanism of change was a non-thermal one.

Belyaev's study ([2009](#)) showed that cellular effects as a result of exposure to UMTS (3G) signals persisted for up to 72 hours, longer than the stress response following heat shock. The team believe that 3G signals may have more of a biological effect because of the spread spectrum nature of the signal. DNA repair characteristics were different in the group of hypersensitive subjects compared with controls. Significant changes in heat shock protein were found by Calabró ([2012](#)) as a result of exposure to GSM mobile phone frequencies.

Yang ([2012](#)) found that 2.45 GHz signals increased the stress response in rat hippocampus, as measured by changes in heat shock proteins.

Dr Gerard Hyland, Warwick University, believes that the microwave radiation from mobile phones can interfere with the body's own electromagnetic field. Mobile phone systems emit pulses of radiation mainly at a rate of 217 times a second, but also with 4 and 2 Hz frequency components. Partsvania's study ([2008](#)), showed that exposing mollusc neurons to these low frequency fields dehabituated them to intracellular stimuli, thus altering the neuron's normal function.

## DNA

Diem ([2005](#)) and Schwarz ([2008](#)) concluded that UMTS exposure may cause genetic alterations in some human cells at levels considerably below the safety standard. These findings show that DNA damage is not dependent on thermal effects. The data in Diem's paper has been challenged by Lerchl ([2010](#)). Sakurai ([2011](#)) found no DNA changes in human glial cell lines. Professor Christopher Gerner commented "In general, the protein synthesis activity of cells increased tremendously. It appears that cells do notice that some proteins lose their function, therefore, must be compensated for by the synthesis of new proteins. As a result, cells experience stress."

Cellular nuclear abnormalities, (indicative of potential DNA changes) were found in the mouths of mobile phone users, particularly in those who spent more than 5 hours a week on their phone (Souza [2013](#)).

DNA damage was found in a study of 14 healthy adults (Ji [2004](#)) exposed to mobile phone radiation for 4 hours. The authors suggested that the radiation increased free radicals in blood cells.

Panagopoulos (2007) found cell death and DNA fragmentation in the early stages of fruit fly adulthood as a result of a few minutes a day exposure to mobile phone radiation. Irreversible DNA changes in the calf thymus were found after a short exposure by Hekmat (2013). Mancinelli (2004) found that microwave radiation at 1.95 MHz represented a potential risk for protein "misfolding", suggesting that RF could have biochemical and biological effects on cells. Studies by Zeng (2006), Zhao (2006) and Remondini (2006) suggested that protein expression changes induced by RF radiation may affect many biological processes to do with signal transduction, and DNA damage and repair. Scientists in the AUYA report proposed that it was vibrations within the oxygen-hydrogen bonds responsible for stabilising three dimensional protein structures which cause a weakening of these bonds.

The effects observed from the exposure to GSM and UMTS show a significantly increased protein synthesis activity in exposed cells after 8 hours. With 8 hours of exposure, the effect occurs reliably in reactive cell types - so long as the cells are provided with a 10-minute break after every 5 minutes of exposure during the entire exposure period; thus the cells will have been exposed to the radiation only for about one third of the time. Based on the fact of an increased protein synthesis, the following mechanism seems plausible at this time: Due to the radiation exposure, resonance oscillations are excited in oxygen-hydrogen bonds, which, in general, are also responsible for heating with microwaves. With their complex three-dimensional structures, proteins are mainly stabilised, among other things, by so-called hydrogen-bond bridges. Thus resonance (in the widest sense of the term) could destabilise the three-dimensional structure through a weakening of the respective bonds. As a result, temporary denaturation and proteasomal breakdown of proteins may occur, which would explain the observation of a compensatory increase in protein synthesis rates. This intermittent exposure (e.g. 5 minute on, followed by a 10 minute break), showed the strongest reaction.

In cases of diseases and pathophysiological conditions, it seems certainly conceivable that symptoms may worsen through the increased protein synthesis as it was observed during mobile phone radiation exposures. Various neurodegenerative disorders are triggered, among other things, because nerve cells show a relatively high rate of protein synthesis, which the protein transport and distribution systems of the cell cannot handle any more.

There are resistant and sensitive cells, which may explain the apparent contradictions. The same cells that showed increased rates of DNA breakage under exposure conditions were also the ones that appeared strongly affected in proteome analyses. Those cells that did not appear to be reactive in studies on DNA breakage also showed hardly any changes or none at all in protein synthesis.

The observed pattern of a generally increased protein synthesis indicates an exposure-dependent protein inactivation. This would also explain why in metabolically active cells naturally occurring DNA breaks - caused by free radicals - are not sufficiently repaired any more, resulting in increased DNA breaks in cells that are exposed. Professor Hugo W Rüdiger "*Chromosomes are much larger units, they contain hundreds or thousands of genes; such a break is a genetic disaster for the cell because it can hardly be reconciled with the survival of the cell. The cell, therefore, tries to make repairs. When doing repairs, the cell indeed survives but at the price of errors, so-called mutations, creeping in. And these mutations are lasting changes, which, in turn, also bear the risk of cancer.*"

Among the different cells, those which are metabolically active respond particularly strongly. This cell property is especially pronounced in growing tissues, in children and young people. These populations are more susceptible to the described effects.

Chromosomal damage in rat foetal tissue as a result of exposure to a non-thermal emission from a mobile phone was also revealed in work done by Ferreira (2006). Belyaev (2006) found that microwaves did not directly induce DNA breaks, but did affect the *expression* of genes. Nikolova

(2005) found double strand DNA breaks after short exposure to RF (6 hours), but not longer exposure (48 hours), whereas Zhang (2008) found gene expression was more obvious with intermittent rather than continuous exposure, and 24 hour exposure had a greater effect than 6 hour exposure (Zhang 2006). Franzellitti (2010) found that RF signals could affect DNA integrity, but that recovery was possible.

Gadhia (2003) found that people who were categorised as smoker-alcoholic were more vulnerable to DNA damage from mobile phone use.

A review of research done by Russian & Ukrainian scientists "*Influence of High-frequency Electromagnetic Radiation at Non-thermal Intensities on the Human Body*" edited by Kositsky, Nizhelska & Ponezha (2001), suggests that as a result of the 'soup' of sources of radiation, standing waves may arise, the frequency of which may coincide with resonance frequencies of living cells, organs or systems of a living being. Exposure to low-energy electromagnetic radiation from high level communications installations may change genetic structures, leading to genomic instability.

Exposing leukaemia cells to RF EMFs for 48 hours caused them to multiply aggressively, overriding the signals that trigger cell death. It seems that the DNA changes either switch off tumour-suppressor genes or switch on oncogenes, the genes that encourage cells to grow.

In 1999, the REFLEX project (QLK4-CT-1999-01574 / REFLEX / Final Report) of 12 research groups in 7 European countries working from 2000 to 2004 found that radiation from mobile phones breaks DNA in human brain cells (confirming Lai & Singh's work in the 1990s), They suggested that "increased formation and activity of free radicals" could be responsible for the damage. There are some questions about some of the research protocols, including the fact that the SARs were high, and the effects of long-term exposure were not addressed. The results of this aggregation of work, known as the REFLEX project, were exclusively obtained in *in vitro* studies and the authors officially concluded that any health risk to people from RF EMF exposure below the presently valid safety limits could not be assessed using these techniques. One can only ask why they then bothered to do the tests?

Despite this rider, the leader of the study, Franz Adlkofer of Verum Foundation advised against using mobile phones when fixed line phones are available, and also recommended using a headset with a mobile phone whenever possible.

As a result of recent research Professor Adlkofer said in a lecture in October 2007 to a forum of scientists in Gelsenkirchen in Germany, that DNA strand breaks in conjunction with the formation of micronuclei does not allow any further doubting of the genotoxic effect of UMTS (3G) signals. "*The DNA strand breaks occur at only 1/40<sup>th</sup> of the guideline limits. Hence, UMTS signals are almost ten times as active as GSM signals.*" His lecture was entitled "Mobile phone radiation damages the genetic material and raises the risk of cancer". Prof Adlkofer called the mobile radiation and the political justifications for it an "*uncontrolled and unplanned field experiment*" on humans.

A study in 2006 from Nylund & Leszczynski found changes in RNA in two cell variants after exposure to 900 MHz radiation, though in a later study they found very little change at 1800 MHz (Nylund 2010). In the first study, the changes were different in the two cell groups, and the authors concluded that "*small genetic differences can influence the cell response to radiowaves*". Huang (2008) and Manta (2017) also found small effects on both genetic expression and regulation. A review of studies by Verschaeve (2009) concluded that a majority showed that RF-exposed individuals have increased frequencies of genetic damage, but due to the shortcomings of some of the papers, further large scale research should be undertaken. Westerman & Hocking (2004)

suggested that RF from mobile phones can cause peripheral neurophysiological changes in some persons.

Nylund & Leszczynski (2004) found that mobile phone radiation might affect the cytoskeleton (the 'scaffolding' within cells) and might have an effect on the physiological functions that are regulated by the cytoskeleton.

Vanderstraeten & Verschaeve (2008) looked at a subset of papers analysing the effect of RF radiation on gene and protein expression. Whilst they concluded that there is definitely sufficient evidence to suggest that further work is needed, they believed that more consistency is required in methodology and results before any conclusions can be drawn.

### **Interaction with other environmental exposures and indirect effects**

Höytö (2008a, 2008b), found that changes occurred in astrocytes (cells in the brain and spinal cord supporting the blood-brain barrier) but not fibroblasts (cells forming connective tissue which plays a critical role in wound healing) after exposure to mobile phone-type signals in cells which had been sensitized by chemical stress, but not in those which had *not* been so sensitized. Li (1999) did not find effects on fibroblast cells, either. This finding may shed some light on the difficulties of study replication and the complexities involved in reactions to environmental stressors. Hou (2014) found that 1800 MHz radiation increased reactive oxygen species (ROS) formation and apoptosis in embryonic fibroblasts (important in wound healing). Xing (2016) demonstrated that 1800MHz EMR induced apoptosis-related events such as ROS burst and more oxidative DNA damage. These findings provide new insights into physiological mechanisms underlying microwave-induced cell apoptosis.

Mathur (2008) also found that chronic intermittent exposure to radiofrequency fields had a number of statistically significant effects on the way rats responded to pain-inducing stimuli. The conclusion was that exposure to EMFs in itself may be insufficient to cause adverse health effects, but it may cause responses to other environmental stimuli to become more severe.

Sometimes it may be that RF radiation can act as a promoter of damage caused by known carcinogens. Manti [2008] found that SARs of 2 W/kg enhanced the effect of X-ray-induced chromosomal damage, though Zhijian (2009) found no such effect. When we are surrounded by proliferating sources of all environmental pollutants it is unclear what synergies may be happening to cause cellular changes.

Dr Andrew Goldsworthy, an honorary lecturer in biology at Imperial College, London, reminds us that exposure to mobile phone radiation allows molecules to cross the barrier protecting the surfaces of the nasal cavity. With the general increase in electromagnetic exposure, we would expect to see a greater penetration of allergens as well as other toxic chemicals. The number of GP diagnoses of allergic rhinitis, which includes allergies to pollen, animal fur and dust mite, rose by a third between 2001 and 2005. Symptoms include a persistently runny nose, sneezing, itching and sore eyes and can last all year round.

Franzellitti (2008) found strong but inconsistent effects in a gene transcript in human trophoblasts (cells providing nutrients to the embryo and which develop into the placenta) from GSM radiofrequency exposure. The authors believed that the effects may not be direct effects, but may be secondary effects caused by more subtle alterations not detected at the protein level.

## Cellular Mechanisms

Andrew Goldsworthy believes that microwave signals from phones weaken cell membranes, which then leak (also Cammaerts [2011](#)). Enzymes can then get into the cell and start digesting it. This causes the fragmentation of DNA, which can cause a loss of fertility and genetic damage to future generations.

Friedman ([2007](#)) showed how mobile phone signals could create free radicals, which could then be involved in the development of cancer, leukaemia, arteriosclerosis, arthritis, Alzheimer's, Parkinson's, MND, etc. Ammari ([2008](#)) showed that high levels of 900 MHz radiation could induce changes in brain cells similar to those associated with some degenerative disorders. At 6W/Kg (the UK limit) microwaves were found to affect brain metabolism and neuronal activity (Ammari [2008b](#)). Beason ([2002](#)) found changes in more than half of bird's brain cells after exposure to 900 MHz signals. 76% of these increased activity and the rest decreased activity.

Karinen ([2008](#)) found protein expression changes in people's skin after RF exposure. Gerner ([2010](#)) found that an 8 hour exposure to an 1800 MHz RF electromagnetic fields caused a significant increase in protein synthesis in metabolically active cells, but not in inactive ones. Neither did they find the effect with a short term exposure. They suggested that these differential effects may explain some of the conflicting results of previous studies. The slower frequencies of digital signals will interact with protein receptors on the cell membrane and cause vibrations which can close down the cell membrane. Nutrient flow is impaired and waste products cannot make it out of the cell. It also disrupts inter-cellular communication so that cell clusters no longer work together effectively. With the increase in waste products free radicals are generated along with messenger RNA which passes on this 'learned response' to daughter cells so that these new cells respond to microwaves in the same way (Anslow 2007 *The Ecologist*).

The processes of cell growth and death in the skin can be significantly altered by an hour of mobile phone exposure (Pacini 2002).

Cell demodulation of digital signals is a process in which the body collects the signal and turns it into electric currents which are carried by ions in the tissues and blood vessels. In real living cells in our brains, ions do not move freely. There are compartments where some ions are permitted to be and some ions are not. The ions are prevented, by various mechanisms, from moving freely. There are gradients of ions forming gradients of electric potentials that are the basis of functioning in our cells and tissues, the brain included. The function of our whole body depends on electric currents.

When the currents contact the cell membrane it tries to vibrate in time with the current. The cell then demodulates the signal so that the low frequency component is extracted and appears across the membrane where it can do the most damage; positively and negatively charged ions are driven in the opposite of their natural direction, the cell membrane destabilises and causes leakage of the cell membrane (Goldsworthy 2009).

One consequence of the leakage is to make the sensory cells of electrosensitive individuals give a whole range of false sensations. People suffering from ES have significantly higher natural rates of membrane leakage as measured by their skin conductance. Since their leakage rates are already high, even small amounts of electromagnetic radiation that would not affect non-sensitive individuals can trigger their symptoms.

Irmak ([2002](#)), Yurekli ([2006](#)) and Lee ([2008](#)) found that animals or human cells (Moustafa [2001](#)) exposed to the level of radiation some people may experience from a mobile phone, suffered oxidative stress, a form of tissue damage, caused by excessive free radicals. Oxidative stress is suspected of being a cause of neurodegenerative diseases such as motor neurone disease. Oral

(2006) found that oxidative stress produced by 900MHz phone radiation produced endometrial damage. Oxidative stress as a result of RF exposure was found to lead to a reduction in serum ferritin level (Fattahi-Asl [2012](#)). RF at 1800 MHz was found to exert oxidative stress on human cells as evidenced by the increase in the concentration of the superoxide radical anion released in the saliva of cell phone users (Abu Khadra [2014](#)). Salivary flow rate and parotid gland salivary concentrations of protein were significantly higher on the right side compared to the left in those that predominantly held mobile phones on the right side. In addition, there was a decrease in concentrations of amylase, lipase, lysozyme, lactoferrin and peroxidase (Hashemipour [2014](#)).

Some altered parameters of the complete blood count and serum chemistry were seen in rats exposed for one year to both CDMA and WCDMA RF simultaneously (Jin [2011](#)).

Orendáčová ([2010](#)) found age-dependent changes in neurogenesis as a result of RF radiation, which may indicate different windows of effect.

Rağbetli ([2010](#)) found mobile phone exposure decreased the number of Purkinje cells in the cerebellum. These are involved in the control of motor movement. Haghani ([2013](#)) also found that prenatal RF exposure altered electrophysiological properties of Purkinje neurons.

The World Health Organisation fact sheet 183 says that exposure to low-levels of RF fields, too low to produce heating, has been reported to alter the electrical activity of the brain in cats and rabbits by changing calcium ion mobility. This finding was supported by Maskey ([2010](#)) in experiments on rats. This effect has also been reported in isolated tissues and cells.

Other studies have suggested that RF fields change the proliferation rate of cells, alter enzyme activity (Barteri [2005](#), Ozgur [2010](#), [2014](#)), affect the genes in the DNA of cells (Kim [2008](#)), or provoke oxidative stress that promotes reactive oxygen species (ROS) production. Dr Howard Fisher exposed samples of brain cells to a mobile phone signal for 60 minutes and found a greater than 10% decrease in cell growth, though Sekijima ([2010](#)) and Dogan ([2011](#)) found no changes.

In a study by Volkow ([2011](#)) 50 minutes of mobile phone radiation significantly raised the brain's level of glucose. Increased glucose levels are associated with inflammation, which may indicate that cells are being damaged in ways that could raise the risk of brain tumours.

When smartphones were used in a bright environment at night, both the circadian illuminance and the values of melatonin suppression were significantly higher (Mortazavi [2016](#)). Melatonin is associated with good quality of sleep and immune system function, so affecting both of these is likely to have an adverse health effect.

However, the World Health Organisation (WHO) does not believe that these effects are well established, nor are their implications for human health sufficiently well understood for them to provide a basis for restricting human exposure. Whilst there is this uncertainty, we would have thought a precautionary response (limiting exposure) would be appropriate.

## Blood changes

Tice ([2002](#)) found serious human blood cell changes following exposure to four different types of cell phone signals. The nuclei of many red blood cells had been split into little bits ("micronuclei") - direct evidence of genetic damage to the cells. This was a well controlled, peer reviewed, and repeated set of experiments that showed a two- to eight-fold increase in micronuclei in the blood that was exposed to cell phone type microwave radiation for 24 hours. D'Ambrosio ([2002](#)) also found micronuclei after microwave exposure that was phase modulated. El-Bediwi ([2013](#)) found that red blood cells, white blood cells and platelets were all broken after exposure to EMFs from mobile phones.

The relationship between the presence of micronuclei and cancer is so strong that doctors from around the world use tests for micronuclei to identify patients likely to develop cancer. Such tests were used extensively after the Chernobyl nuclear accident.

Stopczyk (2002) found that after only one minute of exposure to cell phone radiation, anti-oxidant levels in the blood had dropped significantly. This clearly has implications for many illnesses.

Papers by Mashevich (2003) and Belyaev (2005), report that exposure of human peripheral blood lymphocytes to electromagnetic fields associated with cellular phones leads to chromosomal instability and even apoptosis (Lu 2012). The radiation has a genotoxic effect, elicited via a non-thermal pathway, but can include the same stress response as heat shock. The chromosome change that may be induced is a phenomenon known to increase the risk for cancer. RF levels at half the permitted SAR elicited behavioural signs of microwave-induced thermal stress (Hirata 2010).

Exposure to RF from smartphones triggered activation of neutrophils in vitro (Lippi 2016). The team also found changes in blood function (Lippi 2016b).

As early as 1927, Ernst Muth first discovered that red blood cells exposed to radio frequency waves at levels far less powerful than permitted today line up in chains resembling strings of pearls. In 2002, Bo Sernelius, a physicist at Linköping University in Sweden, calculated what effect EMFs created by different frequencies would have on van der Waals forces, the attractive forces between cells. According to Sernelius' figures, in fields of 850 MHz, the attractive forces appear to leap to micronewton strength. That is a huge jump of around 11 orders of magnitude, and completely unexpected, says Sernelius. If the effect could be confirmed experimentally, it could form the basis of an explanation for tissue damage: stronger attractive forces might make them clump together, for example, or cause blood vessels to contract. Two students of the gymnasium high school in Spaichingen in Germany in 2005 got their fellow pupils to use a mobile phone for 20 seconds and tested the red blood cells. The cells lumped together in 'rolls of coins' immediately after. Ten minutes later the effect could still be seen. For German-speaking readers, see: <http://www.szon.de/lokales/spaichingen/stadt/200503070146.html>. Cells which clump together take up less oxygen and also raise the risk of thrombosis.

The European Research Institute for Electronic Components in Bucharest has found that the radiation emitted by mobile phones causes red blood cells to leak haemoglobin which is important for transporting oxygen within the body. A build up of haemoglobin can cause heart and kidney problems. Mousavy (2009) and Parkar (2010) found that mobile phone radiation decreased oxygen uptake, increased peak heart rate and changed haemoglobin structure.

G & A Gandhi (2005) reported that cells were significantly damaged in peripheral blood lymphocytes in mobile phone users; the cells were highly micronucleated, highlighting a correlation between mobile phone use and genetic damage.

Aalto (2006), Huber (2005) and Kolesnyk (2008) found changes in regional blood flow after exposure to a mobile phone signal, and Oktem (2005) found oxidative damage in the kidneys after exposure to 900MHz radiation.

Kumar (2011) found no effect on the hematopoietic system on in vitro bone marrow cells from a continuous wave 900 MHz source. Maybe the effect on bone marrow cells, rather than cells in a living system is different.

## **Oxidative stress**

The results of the studies reviewed by Dasdag & Akdag ([2015](#)) indicated that mobile phones can cause oxidative stress. Even some of them claimed that oxidative stress from radiofrequencies can result in DNA damage. Kahya ([2014](#)) found that 900 MHz EMR appears to induce apoptosis effects through oxidative stress.

A single EMF exposure in 1800 MHz frequency significantly reduced antioxidant capacity both in healthy animals and those with paw inflammation (Bodera [2013](#)). Marjanovic ([2015](#)) found that modulated RF radiation might cause impairment in cell oxidation within growing cells.

Hidisoglu ([2016](#)) found different effects of EMFs on visual evoked potentials (VEPs) depend on exposure duration. In addition, the results of the study indicated that short-term EMF could provide protective effects, while long-term EMF could have an adverse effect on VEPs and oxidant/antioxidant status.