Radiofrequency EMFs and Health Risks

This article is separated into 8 sections, each of which can be individually downloaded. It is a 'work in progress' incorporating new information whenever time permits.

Section 2

The research – General, Addiction to Hearing

1. Introduction; RF broadcast transmitters (radio & TV); DAB transmitters; radar; mobile phone masts; Internet of Things (IoT); safety zones; Lloyd's of London insurance refusal

2. The research – General; addiction; autism; behaviour changes; blood-brain barrier; blood changes; blood pressure; bone and muscle development; brain activity; cancer; Non-Hodgkin's lymphoma; cellular changes; central nervous system; cognitive changes; dementia; diabetes; DNA; emotional effects; epilepsy; eyes; headaches; hearing

3. The research – heart; effects on heart pacemakers; immune system; kidney effects; lifespan; limb changes in utero; liver damage; medical interference; microwave therapy; multiple sclerosis; neurological changes; effects on the nose; occupational exposure, including pulsed RF; pain; oxidative stress; psychiatric symptoms; skin effects; effects on sleep; spine; spleen and thymus; synergistic effects; thyroid effects; other biological changes; protection; the need for precaution with respect to children; synergistic effects; campaigning organisations

4. General reproductive effects; Radiofrequency (microwave) (RF) exposure and reproductive effects; Mobile phones or phone-type exposure and male sperm; Radiofrequency exposure and effects on female reproduction; Radiofrequency exposure and effects during pregnancy

5. Driving – car systems; tracking vehicles; when your car lock doesn't work; driverless vehicles; road trains; charging electric vehicles; mobile phones; motorbikes; speed limiting devices; traffic control sensors; other in-car devices; interference with electric vehicles

6. Animals; birds and bats; tadpoles; fishes; insects; ants; bees; cockroaches; flies; effects on plants

7. References – 595 references

8. Appendix; table of symptoms, by study; Santini 2002; Freiburger Appell 2002; Navarro 2003; Oberfeld 2004; open letter to Edmund Stoiber, President of Bavaria; Balmori 2005; Hutter 2006; Abdel-Rassoul 2007; Preece 2005; UK Parent-Teacher study 2000; Bortkiewicz 2004; Eger 2004; Wolf & Wolf 2004;

Eberhardt 2008; Augner 2010; Alazawi 2011; Santini 2003; Eger & Jahn 2010; Singh 2016; Kato & Johansson 2012; Gomez-Perretta 2013; Bortkiewicz 2012

The research – General, addiction to hearing

Palumbo (2008), Ruediger's review (2009), Cucuracha's review (2013) and Yakymenko's review (2015) of publications looking at the health effects of radiofrequency electromagnetic fields (RF-EMF) concluded that *"there is ample evidence that RF-EMF can alter the genetic material of exposed cells in vivo and in vitro and in more than one way. This genotoxic action may be mediated by microthermal effects in cellular structures, formation of free radicals, or an interaction with DNA-repair mechanisms."* Garaj-Vrhovac (2009) and Zuo (2014) found evidence of basal and oxidative DNA damage after exposure to microwave radiation. Ruediger also said the studies showed that RF-EMF enhanced the genotoxic action of other chemical or physical agents. Naziroğlu (2012) found an increase in free radicals following RF exposure. Nonionizing RF exposure is capable of inducing PARP-1, a nuclear enzyme which plays an important role in the repair of damaged DNA (Q He 2016).

López-Furelos (2016) investigated the potential effects of RF exposure at 2 different frequencies, 900 MHz and 2450 MHz. They found that the absorbed energy and/or biological effects of the combined signals were not additive, suggesting that multiple signals act on nervous tissue by a different mechanism.

Out of 109 epidemiological studies conducted in the People's Republic of China over the period 1994-2006, 108 reported health effects. Quoting Cao (2007): *"No matter what the exposure level may be, lower or higher than [the Chinese] EMF exposure limits for public, health effects had been reported in these papers. ..."*

An enormous growth in the telecommunication industry has led to an increase in the usage of a number of wireless devices. Symptoms seen in female IT workers were headaches, tremors, depression, blurred vision, irritability, difficulty concentrating, chronic pain, pain in teeth and deteriorated fillings, allergies, asthma, skin problems and dryness of lips, tongue, mouth and eyes. The males had poor short-term memory, difficulty sleeping, fatigue and eye-related problems (Saravanamuttu & Dorairaj 2016).

However, Röösli (2010, 2011) in literature reviews of articles concluded that there was insufficient data to draw firm conclusions about health effects from long-term low-level RF exposure. Lewicka (2015) found oxidative stress, which may lead to free radical diseases after exposure to RF from physiotherapy equipment, LCD monitors and especially car electronics.

Viel (2011) measured personal exposure to radiofrequency radiation and found significant variability between individuals, depending on the day of the week. The authors wondered whether the day of the week in population studies may be an important confounder.

Vagdatli (2014) found that the use of mobile phones and computers affects the function of haematology analysers, leading to false results in experiments. The results obtained demonstrated a statistically significant decrease in neutrophil, erythrocyte, and platelet count and an increase in lymphocyte count, mean corpuscular volume, and red blood cell distribution width, notably in the B4 group, where 4 mobile phones were in use.

Carpenter (2013) concluded from his review that *"excessive exposure to RF radiation increases risk of cancer, male infertility, and neurobehavioral abnormalities."*

Dr Dariusz Leszczynski from STUK, the Finnish governmental authority for the nuclear industry, reported after the 5th International Seminar in China in April 2009, the Chinese concern over ICNIRP and WHO evaluation of RF research. The negative studies seem accepted without

scrutiny, whereas the positive studies are examined in every detail, even though the negative studies might include erroneous results or interpretations. Only the positive studies have to be replicated before they can be accepted as valid, but not the negative ones.

Essex University consistently reports negative findings as a result of exposure to masts (Eltiti 2007, 2009, Wallace 2010, 2011). We have heard that people with electrical sensitivity refuse to take part because of their subsequent health reactions to the exposure. There are insufficient people taking part for the results to achieve statistical significance.

Symptoms such as nausea, headache, dizziness, irritability, discomfort, nervousness, hypertension, depression, sleep disturbance, memory loss, concentration difficulties, reduction in salivary secretion and lowering of libido were statistically significant in people living within 300 metres of mobile phone base stations, compared to those living further than 300 metres (Santini 2003, Alazawi 2011, Shahbazi-Gahrouei 2014), Singh 2016). Headaches and impaired memory effects were reported by people living 100-150 metres from masts (Bortkiewicz 2012).

Various hypotheses have been put forward about how radiofrequency exposure may create the effects reported. Among these are that the radiation reduces melatonin levels and increases nitric oxide (NO) levels. A study by Yariktas (2005) found that melatonin prevented the build-up of NO in the nasal and sinus mucosa after rats were exposed to 900 MHz radiation. These changes in melatonin and nitric oxide levels may reduce the amount of cancer fighting cells in our bodies, promote sleeping disorders, increase cholesterol levels leading to greater risk of atherosclerosis and coronary heart disease, and increase blood pressure giving greater risk of blood clots and strokes.

Maskey (2010) showed calcium ion changes which could affect neuronal connectivity and integration.

All the living cells in our bodies are surrounded by membranes just 2 molecules thick. Most of these molecules are negatively charged and tend to repel one another. However, they are held together by positive ions (mainly calcium) that fit in between them. The ions' forces of attraction for the negative molecules on either side help to bind them together like mortar holding together the bricks of a wall. Extremely weak alternating EMFs, similar to those produced by WiFi, mobile phones, DECT phones and their base stations, can act on these calcium ions and dislodge them. This weakens the membrane and makes it more inclined to leak (Andrew Goldsworthy). This leakage has unwanted biological effects such as allowing toxins, carcinogens and allergens to enter cells more easily. The leakage of digestive enzymes through their internal membranes can damage the DNA. Pulses carried by microwaves are particularly dangerous. This is because their very short wavelength allows the transmission of pulses with extremely rapid rise and fall times, and it is the rate of change of the fields (rather than their total energy) that does most of the biological damage; it catapults vital calcium ions away from cell membranes, making them leak.

Zhang (2013) suggested that neuron injury caused by RF-EMF exposure could partially involve abnormal activity of p25/CDK5.

Pulse-modulated RF radiation caused oxidative injury in liver, lung, testis and heart tissues mediated by lipid peroxidation, increased level of NOx and suppression of antioxidant defense mechanism, in a study by Esmekaya (2011). Ozgur (2010) found oxidative damage to the liver of guinea pigs, proportional to the duration of exposure that was mediated by the treatment with antioxidants. Furtado-Filho (2014) reported that 950 MHz EMFs change the concentrations of polyunsaturated fatty acid (PUFA) in neonates. For rats of 30 days, no oxidative stress, but it is genotoxic to the livers of the rats exposed to total body irradiation. Ragy (2015) reported that exposure of rats to a 900 MHZ EMF could induce oxidative stress in the brain (also Hidisoglu 2016), liver and kidneys and change some blood parameters. Bodera (2015) found that exposure

of rats to an 1800 MHz electromagnetic field might increase lipid peroxidation in the brain, blood and kidneys and that co-exposure to tramadol could show a synergistic effect.

Eskamder (2012) found a significant decrease in various hormone profiles after exposure to RF radiation either from mobiles or base stations. The effects were on the pituitary-adrenal axis. Sangün (2015) suggests that the amount of studies indicating the increased risk of cancer, haematologic effects and cognitive impairment cannot be ignored. There are growing number of studies which reveal the impacts of RF on metabolism and endocrine function. Reproductive system and growth look like the most challenging fields. However there are also some concerns on detrimental effects of EMFs on thyroid functions, adrenal hormones, glucose homeostasis and melatonin levels.

Lee (2009) found no observable adverse effects on mouse foetuses after maternal exposure to CDMA and WCDMA during pregnancy. Combined exposures to 849 MHz and 1.95 GHz @ 2.0 W/kg each did not increase chronic illness in rats (Jin 2011), although there were some changes in the blood. Their exposure is greater than that when using a mobile phone, so it may be that the body's protective mechanisms had disposed of mutant cells. It has been shown in a lot of research that there is not a straightforward dose-response relationship between exposure and health impacts. Kismali (2012) found minor changes in some blood chemistry parameters in pregnant rabbits exposed to 1800 MHz GSM-like signals. The 'remarkable' increases were in enzymes that get more released if muscle or heart muscle tissue is injured. The authors concluded *"studies like this will help establish international standards for the protection of pregnant women from environmental RF radiation."* In an experiment by Hässig (2014) non-ionizing radiation (NIR) from mobile phone base stations resulted in changes in enzyme activities. Certain enzymes were disabled, others enabled by NIR. Furthermore, individual behaviour patterns were observed. While certain cows reacted to NIR, others did not react at all, or even inversely.

A paper by Matronchik & Belyaev (2008) suggested that it is the interaction of environmental exposures that may have biological effects, that non thermal effects of microwaves are dependent on carrier frequency and also static magnetic field in the area of exposure. This could help to explain inconsistencies in study results. Repeated exposure from a 3W 2.45 GHz source had a stronger effect on rat brains than shorter exposures from a 12W source (Jorge-Mora 2011). Using the right exposure is essential to establish the reality of RF effects.

Some toxic biological markers were triggered by the combined stress of non-thermal irradiation and the toxic effect of picrotoxin on cerebral tissues (Carballo-Quintás 2011).

Dr Larry Rosen, a Californian psychologist, is concerned that the use of new personal gadgets may be making some of us mentally ill, especially those prone to narcissism, depression, or obsessive-compulsive disorder. He wonders whether the constant use of technology may be re-wiring our brains. His book, *"iDisorder: Understanding Our Obsession with Technology and Overcoming Its Hold on Us"* contains useful tips about living with technology.

Vijayalaxmi & Scarfi (2014) reviewed the conclusions on the biological effects of RF exposures from various national and international expert groups, based on their analyses. In general, the expert groups suggested a reduction in exposure levels, precautionary approach, and further research.

Bouji (2012) found that GSM exposure affected neuro-immunity, stress and behavioural parameters in middle-aged rats.

Addiction

People with Internet Gaming Disorder (IGD) showed dysfunctional changes in the prefrontal lobe in an fMRI study (Meng 2015, Wang 2015). The authors considered the overlapped role of prefrontal lobe in the reward and self-regulatory system, our results provided supportive evidence for the reclassification of IGD as a behavioural addiction. Yuan (2011) studied adolescents with what was described as 'internet addiction disorder'. Internet addiction after launching smartphone is becoming serious (Kim 2013). Exercise rehabilitation can treat both physical symptoms at first and mental problems in the next step. The results suggested that long-term internet addiction would result in brain structural alterations, which probably contributed to chronic dysfunction. Internet addiction is recognised as a mental disorder and leads to a widespread and significant decrease in functional brain circuit connectivity (Hong 2013a). Male adolescents with internet addiction have significantly decreased cortical thickness, reflecting a shared neurobiological marker of addiction-related disorders in general (Hong 2013b).

Youngsters behaviour seems to indicate some degree of addiction, though without specifying it as such. Kiatrungrit & Hongsanguansri (2014) form the Department of Psychiatry, Ramathibodi Hospital, Mahidol University, Bangkok in Thailand found that in young people aged 15 years old give or take a year or two, 94% had mobile phones, 77% had a television in their bedroom, and 47% had internet access in their bedroom. Over the prior day 39% had watched television shows or films for more than 3 hours, 28% spent more than 3 hours on social networking sites, 25% listened to music for more than 3 hours, and 18% played computer games for more than 3 hours. Overall, 27% reported using electronic devices for more than 12 hours in the previous day.

Psychological factors play an important part in accounting for addictive tendencies towards social networking sites among Chinese smartphone users in Macau. The three psychological risk factors were low Internet self-efficacy, favourable outcome expectancies, and high impulsivity trait (Wu 2013).

In a study by Tossell (2015) 62% of previous non-users of smartphones agreed or strongly agreed that they were addicted to their iPhones after a year. Addicted users spent twice as much time on their phone and launched applications much more frequently (nearly twice as often) as compared to the non-addicted user. Mail, Messaging, Facebook and the Web drove this use.

Autism

Robert Kane (2004) has suggested a possible link between the increased incidence of autism and foetal or neo-natal exposures to RF radiation.

The neurons in the brain of a newly born child makes countless new connections, the patterns of which store what the child has learned. However, after a matter of months, connections that are rarely used are pruned automatically so that those that remain become hard-wired into the child's brain processes. The production of too many and often spurious signals due to electromagnetic exposure during this period will generate frequent random connections, which will not get pruned., or more randomly in a child who is exposed electromagnetically, leaving him or her with a defective hard-wired mind-set. Thornton (2006) suggests that environmental EMFs in infants may disrupt mirror neuron function, leading in turn to the pattern of deficits associated with autism.

Andrew Goldsworthy has suggested some very convincing hypotheses about the link between the increasing incidence of autism (increased by 30% to one in 68 children since 2012 in the US, McCarthy 2014) and RF radiation, including that from smart meters. Radiation at low levels has

direct electrical effects. These are mainly on electrically charged cell membranes, where the low frequency pulses from the modulated microwaves makes them vibrate and leak. This can give rise to many 'modern illnesses' ranging from ES to cancer and disorders of the immune system (Johansson 2009). The strength of the radiation appears to be less important than the duration and pattern of the exposure, with intermittent and repeated exposure being the most damaging. The strong regular transmissions from wireless smart meters are particularly harmful and more likely to lead to DNA damage, cancer and autism. Biological effects from other scientific papers have also shown loss of fertility, brain damage due to the disruption of the blood-brain barrier (Wang 2015) and neuronal hyperactivity leading to autism in children. Many of these effects can be attributed to the loss of structurally important calcium from cell membranes, which make them leak. This can disrupt normal metabolism and also release DNase (which destroys DNA) from the internal structures that normally recycle waste into the rest of the cell.

He continues, living cells have a range of negative feedback mechanisms that sense non-thermal radiation damage and use it to trigger various defence systems. These systems are expensive in energy and resources and also reduce metabolic efficiency. The object therefore has to be to keep this damage within 'tolerable' limits rather than to eliminate it. They do this by cutting in only when they approach the limits of toleration. The effect is to keep the damage at or close to these 'trigger points' over a wide range of radiation levels, ranging from that due to a mobile phone handset held close to the head, to that from a mast, which may be hundreds of metres away.

Continuous irradiation from mobile phone base stations, DECT phone base stations and WiFi routers may not allow adequate recovery time, so chronic irradiation from these sources could be far more damaging and more likely to result in cancer, allergy-related conditions and electromagnetic hypersensitivity. There is some evidence that perinatal exposure to mercury is significantly associated with an increased risk of developmental disorders such as autism spectrum disorders and ADHD (Mortazavi 2016) and decreased levels of neurotransmitters dopamine, serotonin, noreprenephrine, and acetylcholine in the brain and can cause neurological problems. The authors previously showed that exposure to MRI or microwave radiation emitted by mobile phones can lead to increased release of mercury from dental amalgam fillings.

The reason why we are not all affected is that 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. Other people may have had their defence systems impaired by either illness or prolonged electromagnetic exposure. It also seems that the effects of EMF on biological channels are frequency dependent, with a maximum effect at 930 MHz (Ketabi 2015).

The duration of the radiation seems to be more important than its strength, with the effects being cumulative as more and more cells are damaged. Interestingly, DNA damage from mobile phone radiation is greater when the exposure is intermittent than when continuous (Diem 2005). this may be because the cells are constantly adapting and using energy to defend themselves; they drop their guard during the off period and are caught unawares when it goes on again. This constant switching uses more energy, which eventually leaves the cells less able to counteract the effects of the radiation. Diem also found that the effect on DNA damage was still greater if the microwaves were pulsed or modulated to carry information (stopping and starting suddenly).

Smart meters, which operate 24/7 and radiate modulated microwaves intermittently, can therefore be expected to be particularly harmful to DNA. The regular transmissions from wireless smart meters can be expected to have much the same effect, with younger people being more at risk. This is possibly because their brain structure is still growing and developing and therefore more susceptible to damage leading to cancer.

The greatest damage from microwaves is when the brain is first developing in the foetus and the very young child, when it can lead to autism. Dr Dietrich Klinghardt has recently shown the relationship between microwaves and autism; a summary of his work can be found at http://electromagnetichealth.org/media-stories/#Autism

There has been a 60-fold increase in Autism Spectrum Disorder (ASD) in recent years, corresponding in time to the proliferation of mobile telecommunications, WiFi, and microwave ovens as well as extremely low frequency fields (ELF) from mains wiring and domestic appliances. We can now explain this in terms of electromagnetically-induced membrane leakage leading to brain hyperactivity and abnormal brain development.

The first effect of non-ionising electromagnetic radiation is to generate small alternating voltages across the cell membranes, which destabilise them and make them leak. This can have all sorts of consequences as unwanted substances diffuse into and out of cells unhindered, and materialise in different parts of the cell that are normally kept separate, become mixed.

We have known since the work of Suzanne Bawin in the 70's that modulated radiofrequency electromagnetic radiation that is far too weak to cause significant heating can nevertheless remove calcium ions (positively charged calcium atoms) from cell membranes in the brain. Carl Blackman in the 80's and 90's showed that this also occurs with ELF but only within one or more *"amplitude windows"*, above and below which there is little or no effect. A proposed molecular mechanism for this can be found in Goldsworthy (2010). In particular, it explains why weak electromagnetic fields can have a greater effect than strong ones and why prolonged exposure to weak fields (where cells are maintained in the unstable condition for longer) is potentially more damaging than relatively brief exposure to much stronger ones.

Behaviours in Autism Spectrum Conditions (ASC) may emerge from alterations of brain electrophysiology, and EMF/RF could contribute to these by de-tuning the organism. A paper by Herbert & Sage (2013) details evidence for mitochondrial dysfunction, immune system dysregulation, neuroinflammation and brain blood flow alterations, altered electrophysiology, disruption of electromagnetic signaling, synchrony, and sensory processing, de-tuning of the brain and organism, with autistic behaviours as emergent properties emanating from this pathophysiology. EMF/RFR exposure can worsen challenging biological problems and symptoms and reducing exposure might ameliorate symptoms of ASCs by reducing the problems of physiological repair.

The incidence of autism has increased 60-fold, in parallel with the increase in electromagnetic pollution over the last 30 years. The chance of having an autistic child may now be as high as one in 50. Apart from the personal tragedies for the affected children and their families, autism is of enormous economic importance. In the UK alone, the annual cost to the Nation in care and lost production exceeds the annual tax revenue from the entire mobile phone industry, which is about £20 billion (Goldsworthy 2012). In theory the Government could close down the entire mobile phone industry and make a profit! There are ways in which the modulation of the signal can be changed to avoid this, but in the meantime, the compulsory introduction of smart meters can only contribute further to autism on a grand scale.

Behaviour changes

Despite exposure to radiofrequency fields being below the reference level, conduct problems and abnormal mental behaviour was found in adolescents and children (Thomas 2010). The fields were measured using a personal dosimeter.

Exposure to 905 MHz radiation for 2 hours increased anxiety, reduced locomotor, orientation and exploration activities in female rats and orientation and exploration activities in male rats. The effects persisted 1 day after the exposure (Khirazova 2012). Júnior (2014) also found stressful behavioural patterns in rats following 1800 MHz RF exposure.

Microwave radiation caused body mass decrease and anxiety related behaviour in rats, which was alleviated by melatonin supplementation (Sokolovic 2012).

Blood-brain barrier

20 minute radiofrequency exposure to 900 MHZ and 1800 MHz significantly increases the permeability of the blood-brain barrier of male, but not female rats (Sirav & Seyhan 2009). The permeability of the blood-brain barrier was found to be increased when male rats were exposed to 900 MHz and 1800 MHz radiation and in female rats when exposed to 900 MHz radiation (Sırav & Seyhan 2016).

Highly significant levels of neuronal damage were found in the cortex, hippocampus and basal ganglia in the brains of rats exposed to RF from GSM mobile phones (Salford 2003).

Blood changes

RF radiation at 900 MHz affected the speed and direction of movement of neutrophils (Aly 2008), which may be significant in that neutrophils have an important role in killing pathogens in the body.

Microwave radiation decreased microvascular diameters and blood perfusion, increased the permeability of microvessels. It induced the formation of stress fibres, apoptosis, and LDH leakage from microvascular endothelial cells. Also, when microvascular endothelial cells were exposed to microwaves, protein synthesis was significantly elevated (Y Li 2014). Sagioglu (2015) found that all RF exposure protocols resulted in an increase of apoptotic cell death (ACD) observed in newly emerged flies in egg chambers, even at very low electric field strengths. FM waves seem to have a stronger effect in ACD than continuous waves. They showed that with regard to intensity and temporal exposure pattern, EMF-biological tissue interaction is not linear in response. The intensity threshold for the induction of biological effects depends on frequency, modulation and temporal exposure pattern.

Kazemi (2015) found that human blood exposed to a 900 MHz GSM signal could induce oxidative stress in monocytes, cells involved in biological defence systems.

In a study by Trosić (1999) looking at blood biomarkers following 2450 MHz radiation, the results of peripheral blood cell response suggested a decreasing tendency in total leukocyte count and in relative lymphocyte count in the treated group. A slight increase was also observed in granulocyte count and in the absolute count of peripheral blood erythrocytes.

Achudume (2010) showed some biochemical changes that may be associated with a prolonged exposure to electromagnetic fields within 300 metres of mobile phone base stations and their relationship to the activity of the antioxidant system in rat. Taheri (2017) reported that RF exposure from mobile phone base stations influenced the blood and immune systems; the whole number of white blood cells, the level of haematocrit, percent of monocytes, eosinophils and basophils were significantly lower than the control group. The number of red blood cells, their average volume and the mean concentration of haemoglobin were notably higher than the controls. Various antioxidants in the plasma of people living near mobile phone masts were reduced (Zothansiama 2017), and there was evidence of DNA damage.

Blood pressure

One person who reacts to RF radiation checked his blood pressure readings; first thing 120/70, and then surrounded by electrosmog at work 189/106, 160/104 and 158/103.These readings, of course, could have changed for other reasons, but as this effect has been widely reported, we would like to see further detailed investigations carried out.

High blood pressure increases the risk of developing dementia, being 6 times more likely in people with high blood pressure in their 40s and 50s; the exact mechanism is unclear, but it has been suggested that high blood pressure can starve the brain of bloodflow and the oxygen it carries. The NHS has been under increasing pressure to provide care facilities for people with early onset dementia. If the increase in ambient RF exposure is responsible for changes in blood pressure, this could be one explanation. Melatonin supplementation may help, as it has been shown to reduce the damage caused by changes in bloodflow.

A study by Spichtig (2012) found that intermittent exposure to RF had small short- and medium-term effects on cerebral blood circulation and heart rate. Szmigielski (1998) found occupational exposure to radiofrequency EMF can result in changes of the diurnal rhythms of blood pressure and heart rate.

Bone and muscle development

Bone and muscle tissue development was negatively affected due to prenatal exposure to 1800 MHz RF (Erkut 2016).

Brain activity

Tattersall (2001) found that low-intensity RF fields could modulate the excitability of hippocampal tissue in vitro in the absence of gross thermal effects. Ultrastructural and functional changes were induced in hippocampal neurons of rats (Baş 2013) and in PC12 cells exposed to microwave radiation by Wang LF (2015).

Arns (2007) found a subtle slowing of brain activity within normal physiological ranges related to mobile phone use. Hamblin (2004) found that mobile phone radiation may affect neural activity, particularly in proximity to the phone. Effects were greatest over the right hemisphere and midline sites (closest to the active mobile phone).

S Xu (2010) found that 1800 MHz RF radiation could cause oxidative damage to mitochondrial DNA (mtDNA) in primary cultured neurons. Defects in mtDNA are closely associated with various nervous system diseases. The authors believed that this oxidative damage to mtDNA may account for the neurotoxicity of RF radiation in the brain.

Lv (2013) showed that 30min LTE RF-EMF exposure modulated the spontaneous low frequency fluctuations in some brain regions. A further study by Lv in 2014 showed short-term LTE EMF exposure would modulate the synchronization patterns of EEG activation across the whole brain. Acute exposure of the human ear to a 3G mobile phone electromagnetic field could result in changes in the EEG, which indicates that the brain can detect these intensity peaks (Roggeveen 2015). The authors were unsure what effect these changes might have. In a review by Politanski (2016) on published research, results show EMF effects on resting EEG and EEG during patients' sleep and the influence of radiofrequency EMF on the cardiovascular regulation.

Akbari (2014) reported that RF caused oxidative stress in the brain, as did Hussein (2016), who also found DNA damage and histological changes. RF-EMR exposure for a month induced

oxidative stress in rat brain, but its magnitude was different in different regions studied (Narayanan 2014). It was suggested that RF-EMR-induced oxidative stress could be one of the underlying causes for the behavioural deficits seen in rats after RF-EMR exposure.

Kesari (2009, 2011) concluded that cell death and changes in enzyme activities was related to an overproduction of reactive oxygen species in animals under mobile phone exposure.

The genes underlying some aspects of neurotransmitter regulation, blood-brain barrier and melatonin production in the brain were affected by 915 MHz GSM exposure (Belyaev 2006).

In the study by Q Wang (2005) GluR2 protein of neurons exposed to 900 MHz fields was significantly down-regulated, while intracellular calcium ions were significantly up-regulated.

900 MHz radiation was found to change brain metabolism in healthy rat brain tissue (Dasdag 2012).

Cancer

Cancer has not been the most reported health effect from environmental microwave sources. One of the reasons for this is likely to be the length of time between exposure to an environmental pollutant and the time that a cancer takes to be diagnosed. This often takes longer than the length of time many populations have been exposed to environmental microwave radiation. There are likely to be some differences in genetic susceptibility that make epidemiological research more difficult (Czyz 2004).

Dr Anthony B. Miller is a physician epidemiologist who specializes in cancer aetiology, prevention, and screening. Miller is Professor Emeritus at the Dalla Lana School of Public Health of the University of Toronto, an expert cancer researcher and advisor to the World Health Organization International Agency for Research on Cancer. Dr Miller has stated that radio frequency (RF) radiation from any source fully meets criteria to be classified as a "Group 1 carcinogenic to humans" agent. It is currently classified as group 2B 'possibly carcinogenic' (September 2017).

A cluster of leukaemia cases were found by Michelozzi (1998) near a high power radio transmitter in a peripheral area of Rome, with a significantly higher mortality rate amongst men. There was a significant decline in risk for men with distance from the transmitter. It seems to point to some form of hormonal link.

In 2010, the following information was revealed in a study of mortality from leukaemia and lymphoma in adults and children. Adults exposed for at least 10 years, living within 5 and 9 kilometres from the Vatican radio transmitter, were 3 times more likely to develop leukaemia or lymphoma than those living further away. The risks were higher for women, and those over 21. When the distance was extended to 12 kilometres, the risk for all adults increased to 7 times. For children who had lived most of their lives between 6 and 12 kilometres of the Radio Vatican transmitter were 5 times more likely to develop leukaemia and lymphoma. Long-term intermittent exposure to RF fields increased the risk of developing lymphomas in cancer-susceptible mice.

However, two studies found that people living near a mobile phone mast were 3 times (Eger 2004, Eger & Neppe 2009) or over 4 times (Wolf & Wolf 2004) more likely to develop cancer than those living in an area away from the mast, and Eger found that people became ill much earlier. Wolf & Wolf reported that women were more than 10 times more likely to develop cancer. No particular type of cancer was identified as being more likely to develop. Geographical areas covered by several transmitters show higher incidences of melanoma than areas covered by one

transmitter (Hallberg & Johansson 2009). Yakymenko (2011) reported that a year of operation of a powerful base station resulted in a dramatic increase in cancer incidence in the nearby population.

Residents in Sandwell, West Midlands were concerned about the number of people developing cancer in the vicinity of a mobile phone mast. A study of the area (Stewart 2012) over 4 3-year time periods found that the number of people did not fulfil the criteria for a cancer cluster, but females had more neoplasms, in one of the periods looked at. There were no significant differences for colorectal, female breast and prostate cancers. The authors concluded that it is unlikely that information around a single base station can either demonstrate or exclude causality.

Firefighters have been reported as having an increased risk of dying from cancer, including leukaemia, multiple myeloma, non-Hodgkin's lymphoma, male breast cancer, malignant melanoma, and cancers of the brain, stomach, colon, rectum, prostate, urinary bladder, testes and thyroid (Milham 2009). This list strongly overlaps the list of cancers at increased risk in workers exposed to EMFs and RF radiation. There was a higher risk of male breast cancer in man older than 60 and a higher risk of testicular cancer in men younger than 40 (mainly non-seminoma, the more malignant type of testicular cancer). Although exposure to carcinogens in combustion products could be a contributory factor, respiratory system cancers and diseases are usually not increased in firefighters as they are in workers exposed to known inhaled carcinogens. Firefighters have increased exposure to RF radiation in the course of their work, from the mobile two-way radio communications devices which they routinely use while fighting fires, and at times from fire station and fire vehicle radio transmitters.

Cancer incidence was examined in Polish military personnel exposed to RF (Smigieldski 1996). There were higher incidence rates in those developing neoplasms of the alimentary tract, brain tumours and malignancies of the haemopoietic system and lymphatic organs. Among malignancies of the haemopoietic/lymphatic systems, the largest differences in incidence were for chronic myelocytic leukaemia, acute myeloblastic leukaemia and non-Hodgkin lymphomas.

Among 25 radar technicians in the 20-37-year age group with high levels of exposure to RF/MW radiation, the following cancers were diagnosed; melanoma of the eye, testicular cancer, nasopharyngioma, non-Hodgkin's lymphoma, and breast cancer. Latency periods were extremely brief (Richter 2000). A study of female radio and telegraph operators showed an association between occupational exposure to EMF and increased risk of breast cancer (Kliukiene 2003).

Occupational exposure to RF has resulted in central nervous system changes, cardiovascular effects including artherosclerosis, ischaemic heart disease and coronary insufficiency rapid progressive expansion (Suvorov 2013). The same study found that people living near radar installations have experienced vegetative dystonia, thrombocytopenia, decrease in blood coagulation index, and thyroid function changes.

Young military radar workers developed brain tumours within 10 years of initial occupational exposures, some at less than 30 years of age (Richter 2002). Degrave (2008) too, found that younger people exposed occupationally to radar had an increased risk of developing haemolymphatic cancers. Occupational exposure to radar was found to lead to changes in somatic symptoms, anxiety and insomnia, social dysfunction and severe depression (Dehghan 2013).

Amateur radio operators and those who worked with radar equipment were found to have an increased risk of testicular cancer (Hardell 1998).

In a review of nine cohort studies dealing with the biological effects on human health from occupational exposure to radiofrequencies/microwaves, published between 1980 and 2002, Breckenkamp (2003) found that in most of the studies, an increased risk for various types of cancer was found in exposed study participants, although in different organs.

Paternal exposure to some types of equipment that emit radiofrequency radiation was positively associated with neuroblastoma (De Roos 2001).

Thirteen children attending La Asunción secondary school in Gijón, Spain, mapped the beams of radiation emitted by the 92 base stations in their city (reported in La Nueva España 20.06.05). They then pinpointed all of the houses of people who had developed cancer during the previous 5 years. They found that:

a) Cancer rates were abnormal in the locality of base stations (the area was exposed to higher levels of radiation)
b) The cancer rates were highest where 2 or more beams crossed

In November 2009, Malagahoy reported that among the 350 inhabitants of Pérez Los Cortijos, near Vélez-Málaga, in Spain, there have been 43 cases of cancer resulting in 35 deaths, which are blamed on the phone mast in the village.

In a study by Lerchl (2015), numbers of tumours of the lungs and livers in exposed animals were significantly higher than in sham-exposed controls. In addition, lymphomas were also found to be significantly more common. The authors suggest that these tumour-promoting effects may be caused by metabolic changes due to the RF at low to moderate exposure levels.

There was a significant excess of benign and malignant tumours amongst children exposed to high radiofrequency levels from mobile phone base stations in Taiwan (Li 2012). An increase in leukaemia and brain tumours was found but not at a significant level.

Roland Stabenow, the head of cancer registry in Berlin, informed the residents of Steinbach-Hallenberg that there was a 7 fold increase in breast cancer amongst people in their area living near the cellular antennas.

It is believed that microwaves may interfere with the body's bio-electro-chemical signalling systems, affecting the mechanisms whereby cells become cancerous, and the mechanisms which repair pre-cancerous damage. Pokorný (2008) suggests that interaction forces between cancer cells may be smaller than interaction forces between healthy cells and cancer cells. The mechanism of malignity, i.e. local invasion, detachment of cancer cells, and metastasis, is assumed to depend on the electromagnetic field.

There were severe degenerative changes, shrunken cytoplasm and extensively dark pyknotic nuclei in groups of rats exposed to RF. Biochemical analysis demonstrated that the antioxidative level was significantly decreased and oxidative stress was significantly increased in the frontal cortex, brain stem and cerebellum (Eser 2013). The authors concluded that EM radiation caused structural changes in the frontal cortex, brain stem and cerebellum and impaired the oxidative stress and inflammatory cytokine system. This deterioration can lead to loss of function of these areas and cancer development.

Prenatal and postnatal exposure to RF decreased the weekly weight gain and affected some biochemical parameters, especially the cortex region of the brain (Celikozlu 2012).

Biophotons (BPHs) are weak photons within or emitted from living organisms. The intensities of BPHs range from a few to several hundred photons s(-1) x cm(-2). BPH emission originates from a

de-localised coherent electromagnetic field within the living organisms and is regulated by the field. Chang (2008) discusses the functions that BPHs may play in DNA and protein functioning.

This may explain why no particular cancer is associated with microwave exposure; the immune system's ability to repair cancer damage is compromised, no matter in which area of the body the cancer first appears. Buttiglione (2007) found changes in human neuroblastoma cells after being exposed to 900 MHz radiation, though Billaudel (2009) didn't. Pérez-Castejón (2009) found astrocytoma cell proliferation following very low level exposure to RF.

The study by Hallberg & Johansson (2009) proposed another interesting confounder. Breast cancer more frequently occurs in the left breast among both men and women and melanoma is found more on the left side. They suggest that a high prevalence of breast cancer and melanoma on the left side of the body may be a logical consequence of sleeping in beds having mattresses containing wave-reflecting metal springs. People tend to sleep for longer periods on their right side, apparently to avoid disturbance by the heart beat. This puts the left side further away from the field-attenuating influence of the metal springs in the mattress; thus the left side will spend more time exposed to stronger combined fields from incident and reflected radiation. They thought that it may explain why body parts farthest away from the mattress have higher melanoma rates than the sun-exposed face area.

A new pilot study by Tillmann (2008 page 10) found tumour-promoting effects in mice following chronic exposure to UMTS signals. The levels used were very high, but it does demonstrate RF effects on living systems.

Non-Hodgkin's lymphoma

An increased risk of non-Hodgkin's lymphoma was observed in men occupationally engaged in non-specified rail and road transport jobs, as telecommunications traffic officers and telegraph and radio operators (Cano & Pollán 2001). The authors concluded that the risk excess observed in telecommunication and transport workers could be explained by electromagnetic radiation exposure.

Cellular changes

RF radiation was found to damage cell equilibrium in growing cells (Marjanovic 2014).

Prenatal EMF exposure caused a decrease in the number of granule cells in the dentate gyrus of rats. This suggests that prenatal exposure to a 900 MHz EMF affects the development of the dentate gyrus granule cells in the rat hippocampus (Odaci 2008, Erdem Koç 2016). Melatonin helped protect cells against neuronal damage in the study by Erdem Koç.

Cellular stress caused by electromagnetic fields could initiate changes in cell cycle reaction rates, which may involve heat-shock proteins (Velizarov 1999), or cell cycle progression (Kayhan 2016).

There was a significant increase in buccal cell frequency and tail moment value in people exposed to mobile phone mast radiation (Gulati 2016).

Markovà (2010) found that stem cells are more sensitive to microwave exposure than differentiated cells. The fact that stem cells react to more frequencies may be important for cancer risk assessment.

Lin (2016) found that EMF and RF-EMF exposure can upregulate the expression of genes involved in glucose transportation. Energy metabolism is closely related with the cell response to environmental stress including EMF exposure.

Xing (2016) demonstrated that 1800MHz EMR induces apoptosis-related events such as ROS burst and more oxidative DNA damage, providing new insights into the physiological mechanisms underlying microwave-induced cell apoptosis.

Microwave dose-dependently induced morphological and functional injury in NK-92 natural killer cells, possibly through ERK-mediated regulation of apoptosis and perforin expression (Zhao 2017).

Sun's study (2013) suggested that membrane receptors could be one of the main targets by which RFR interacts with cells.

Central Nervous System

Juutilainen reviewed possible biological effects of RF and concluded that there may be specific effects from amplitude-modulated RF fields on the human central nervous system (2011). This could happen prenatally (Luo 2013). Hemmati (2014) concluded that EMFs may play an important role in neural cell migration by increasing reelin and Dab1 expression in the developing cortex.

Short exposure to electromagnetic radiation was found to be a sub-threshold irritant for the central nervous system (Luk'ianova 2013).

Exposure to GSM electromagnetic fields exerts some effects on the central nervous system, including its auditory evoked potentials (Maby 2006, Bak (2010).

Cognitive changes

Deshmukh (2013, 2015) and Megha (2012, 2015) found that low level MW radiation had significant effects on cognitive function and levels of oxidative stress, including DNA damage. 900 MHz exposure resulted in an impairment in the cognitive processes involved in spontaneous exploratory activity (Maaroufi 2014). Leung's (2011) study provides support for an effect of radiofrequency exposure on human cognitive function and on electrophysiological processes.

Guxens (2016) found inconsistent associations between different sources of RF-EMF exposure, both indoors and outdoors and cognitive function in children aged 5-6 years.

Military occupational exposure to radar microwave radiation leads to decreased reaction time and the lower performance of short-term memory (Mortazavi 2013).

Rat memory was affected, particularly in male rats, more with GSM rather than UMTS RF exposure (Schneider & Stangassinger 2014) and at high SARs (Barthélémy 2016). Megha (2015) found that low-intensity microwave radiation may cause learning and memory disturbances by altering levels of brain neurotransmitters. Impairments in learning and memory were observed in mice exposed to RF (Qin 2014) and rats (Tong 2013). Wang (2013) observed varying degrees of degeneration of hippocampal neurons, decreased synaptic vesicles and blurred synaptic clefts in rats exposed to RF. Hao (2013) found that RF exposure influences learning and memory in rats, but that they could adapt to long-term exposure.

Schmid (2012) found that pulse-modulated RF EMF altered brain physiology, though with considerable individual variability.

Long-term chronic microwave was found to induce cognitive deficit and the 5-HT system may be involved in it (Li HJ 2015).

Dementia

The evidence indicates that long-term significant occupational exposure to RF MF may increase the risk of both Alzheimer's disease and breast cancer (Davanipour & Sobel 2009). The number of people with a diagnosis of dementia in England has risen by 62% between 2006 and 2013 (Kmietowicz 2014). During this time, the use of mobile phones, smartphones, tablets, etc. has increased significantly, including the advent of 4G.

RF enhanced cytotoxicity found in Alzheimer's disease conditions (JY Kim 2017).

Diabetes

In a study by Meo (2015) the authors concluded that exposure to high RF from mobile phone masts is associated with elevated levels of glycated haemoglobin (HbA1c) and risk of type 2 diabetes mellitus.

RF exposure (1h/day during 21 consecutive days) induced a diabetes-like status through alteration of oxidative response (Salah 2013). Olive leaves extract was able to correct glucose metabolism disorder by minimizing oxidative stress induced by RF in rat tissues.

DNA

Nikolova (2005) and Franzellitti (2010) found transient DNA double-strand DNA breakages after some hours exposure to RF. A longer (48 hour) exposure did not have this effect. Campisi (2010) found a significant increase in ROS levels and DNA fragmentation after exposure of the astrocytes to modulated EMF for 20 minutes. Their findings suggested the hypothesis that the effects could be due to hyperstimulation of the glutamate receptors, which play a crucial role in acute and chronic brain damage. Microwave radiation represents a potential DNA-damaging hazard (Diem 2005, Lixia 2006, Garaj-Vrhovac & Oreščanin 2009, Lu 2012, Tkalec 2013, Xu 2013). DNA acts as a fractal antenna when exposed to RF EMFs, where the interactions are indicative of DNA damage, which could account for increases in cancer epidemiology (Blank & Goodman 2011). Wang (2008) suggested that a particular gene, XPD, may confer cancer susceptibility regardless of environmental factors. This could help explain variability in susceptibility.

RF radiation increased levels of aneuploidy (losses and gains of chromosomes, a major "somatic mutation" leading to genomic instability and thereby to cancer) in chromosome 17 (Mashevich 2003). Tice (2002) had found that radiofrequency signals were capable of inducing chromosomal damage in human lymphocytes.

Low level EMF at 2.45 GHz increases the DNA damage in rat brain tissues and plasma and increases protein oxidation in plasma (Deshmukh 2013b). Garlic decreased these effects (Gürler 2014).

Mature and immature rats were exposed to RF and both groups sustained cytotoxic and genotoxic cellular damage (Demsia 2004, Atli Sekeroglu 2013). The authors said that the possible carcinogenic risk of RF should be further studied, especially in children.

An IARC Monographs Working Group reviewed epidemiological evidence, cancer bioassays, and mechanistic and other relevant data to reach conclusions as to the carcinogenic hazard to humans from exposure to these electromagnetic fields. With "limited evidence" for carcinogenicity in humans based on an increased risk of glioma – a malignant brain tumour – among heavy users of mobile telephones, radiofrequency electromagnetic fields were classified as "possibly carcinogenic to humans" (Group 2B) in 2013.

Residence near mobile phone base stations was associated with DNA damage, females being affected more than males. The authors of the study (Gandhi 2015) expressed their concern that the genetic damage needed to be considered with regard to the risk of developing neurodegenerative disorders and cancer.

Zhijian (2010) found that RF did not damage DNA directly, but it significantly inhibited the repair of DNA damage caused by other things. In a further study (Zhijian 2013) differential expression of 27 proteins was found, which were related to DNA damage repair, apoptosis, oncogenesis, cell cycle and proliferation. Sykes (2001) also found that whilst 900 MHz RF radiation may not be directly genotoxic, exposure to RF radiation can lead to a perturbation in recombination frequency which may have implications for recombination repair of DNA.

900 MHz MW-EMF influenced functional pathways of gene expression in acute T-lymphoblastoid leukemia cells (Trivino Pardo 2012). Moraitis (2015) found that exposure to a UMTS 1966 MHz EMF might be related to DNA damage in T lymphocyte cells.

GSM 900 MHz exposure resulted in a significant persistent overproduction of superoxide and nitrogen oxide in embryo cells leading to oxidative damage of DNA. The authors felt that the changes may lead to cancerous transformation of cells (Burlaka 2013).

Radiofrequency radiation was found to affect the DNA in rabbits, including those which were pregnant. The authors (Guler 2010) felt that further studies should evaluate whether the standards for the protection of pregnant women are adequate.

900 MHz RF radiation can alter some of the miRNA, which, in turn, may lead to adverse effects. miRNA, plays a paramount role in growth, differentiation, proliferation and cell death by suppressing one or more target genes (Dasdag 2015).

Emotional effects

Mobile phone radiation exposure reduced the emotionality of rats (as shown in bonding behaviours) whilst it did not affect general locomotion (Narayanan 2012).

Epilepsy

Cinar (2013) found that acute exposure to RF EMFs could facilitate epileptic seizures, independent of exposure time. They suggested that patients with epilepsy may want to take note.

Esmekaya (2016) reported that exposure of mice to a 900 MHz EMF might increase oxidative stress in the brain during an epileptic seizure.

Eyes

Low-power radiation has been associated with lens transparency, alteration in cell proliferation and apoptosis, inhibition of gap junctional intercellular communication, genetic instability and

stress responses in lens epithelial cells (Yu & Yao 2010). Oxidative stress was found in human lens epithelial cells which were exposed to 1800 MHz RF (Ni 2013). Microwave radiation exceeding 0.50 mW/cm(2) may injure lens epithelial cells after 8 hour radiation (Wang 2003).

Electromagnetic 'noise' was found to have a protective effect on lens cells damage induced by microwave radiation (Wu 2008, Yao 2008).

Headaches

Riddervold (2008) found headaches, but not cognitive changes reported by people exposed to RF from mobile phone base stations.

Hearing

GSM like radiofrequency radiation affected hearing function in rabbits (Budak 2009).

An occupational study by Oktay (2004) found hearing loss as a result of RF exposure. Meriç (1998) found70% of people occupationally exposed to RF had hearing loss compared with 6% for an unexposed group.

In a study by Colletti (2011) all the study patients showed a substantial decrease in amplitude and a significant increase in latency of cochlear nerve compound action potentials during the 5 minutes of exposure to EMF. These changes lasted for a period of around 5 minutes after exposure. The powerfrequency fields from the batteries may also have had an effect, but this was not discussed.

Maskey & Kim (2014) found a detrimental effect of RF exposure in the auditory nuclei.

Prenatal exposure to RF led to cellular structural damage in the cochlea during cochlear development in the rat (Seckin 2014).