

Mobile Phones and Brain Tumours – A Public Health Concern

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The completion of this paper on February 7, 2008 follows **14 months of objective research by the author**, involving the critical review of over 100 sources in the recent medical and scientific literature, in addition to Press reports and Internet content. This paper represents a systematic and concise yet comprehensive review of this area to date and its findings highlight **an emerging global public health concern**.

KEY MESSAGES OF THIS WORK:

- Mobile phones are convenient and frequently invaluable, yet exposure to their electromagnetic radiation is invisible. Therefore, any **danger** this exposure poses may be **easily dismissed**.
- E**xposure is long-term** and its effects on the body, particularly its electrical organ, the brain, are compounded by numerous other simultaneous long-term exposures including **continuous waves** from radio and TV transmitter towers, cordless phone base stations, power lines, and wireless/WiFi computing devices.
- A **malignant brain tumour** represents a life-ending diagnosis in the vast majority of those diagnosed. There is a significant and increasing body of evidence, to date **at least 8 comprehensive clinical studies internationally and one long-term meta-analysis**, for a link between mobile phone usage and certain brain tumours.
- Taken together, the data presented below compellingly suggest that the link between mobile phones and brain tumours should **no longer** be regarded as a **myth**. Individual and class action lawsuits have been filed in the USA, and at least one has already been successfully prosecuted, regarding the cell phone-brain tumour link.
- The "incubation time" or "**latency**" (i.e., the time from commencement of regular mobile phone usage to the diagnosis of a malignant solid brain tumour in a susceptible individual) may be in the order of **10-20 years**. In the years 2008-2012, we will have reached the appropriate length of follow-up time to begin to definitively observe the impact of this global technology on brain tumour incidence rates.
- There is currently enough evidence and technology available to warrant Industry and Governments alike in taking **immediate steps** to reduce exposure of consumers to mobile phone-related electromagnetic radiation and to make

consumers clearly aware of potential dangers and how to use this technology sensibly and safely.

- It is anticipated that this danger has far broader **public health ramifications** than asbestos and smoking, and directly concerns all of us, particularly the younger generation, including very young **children**.

CONTENTS:

1. ABSTRACT:

The Abstract is a summary of this paper. It conveys the "take home" message of this report.

Mobile phones are an integral part of Society, with billions of users worldwide across a wide age spectrum. Although the availability of a mobile phone can contribute to the **convenience and safety** of an individual's life, the question arises as to whether **"excessive" use** of a mobile phone can pose a health risk through exposure of a **"heavy" user** to low but repeated and eventually prolonged levels of **electromagnetic radiation (EMR)** at a relatively close proximity ("**near-field**") to the brain, our key electrical organ. Given the widespread use of mobile phones by children and adults alike, the presence of any health risk posed by long-term near-field radiation will inevitably set the stage for the emergence of a **global public health problem**.

The key aim of this paper was to **scientifically and objectively review data** suggesting or refuting a relationship between mobile phone usage and the occurrence of **malignant brain tumours**. Following fourteen months of research involving a comprehensive review of over 100 sources in the recent medical and scientific literature in addition to the Press and Internet, the author concludes that there is a growing body of statistically significant **evidence** for a relationship between the overall **length of use of a mobile phone and the delayed occurrence of a brain tumour on the same side of the head as the "preferred side" for mobile phone usage**. The **elevated risk** (**increased odds**) appears to be in the order of **2 - 4 fold**. It is postulated that some individuals may be more **susceptible** to developing a malignant brain tumour when compared to others exposed to similar durations and strengths of electromagnetic radiation. This susceptibility may be genetically predetermined. The effects of this kind of radiation are likely to be **cumulative and long-term**.

In the context of the fact that widespread mobile phone usage commenced in the mid-1980s (earliest in Northern Europe), with the **first 10 years** of widespread usage ending in the **mid 1990s**, and the fact that **solid tumours** may take **several years** to trigger and form, it seems plausible to expect that if no appropriate changes are made by Industry and consumers alike, in the **next 5-10 years** the aforementioned concerning associations will likely be **definitively proven** in the medical literature. Given this calculated "incubation time" and the commencement of mobile telephony's mass deployment in **Sweden**, it is no surprise that Swedish researchers were among the first to report a positive association between cell phone use and brain tumour risk (see studies quoted below). A 2007 Swedish meta-analysis of the international long-term follow up data confirms this growing concern.

At this time, **precautionary but strong recommendations** for members of the **General Public** include (whenever feasible or possible): (i) using a regular "land-line" in preference to a hand-held mobile or cordless phone; (ii) using a hand-held phone on "speaker phone" mode held > 20 cm away or "in-vehicle hands-free speaker" mode as opposed to the typical "mobile phone-to-ear" use; (iii) minimising the use of current Bluetooth devices and unshielded headphone accessories for mobile phones; (iv) minimising the amount of time spent using mobile and cordless phones for all adults; and (v) restricting the use of mobile and cordless phones by children to emergency situations. For members of the **Telecommunications Industry**, the author recommends expediting the development and promotion of safe, practical and ubiquitous EMR/radiofrequency shielding devices for mobile and cordless phones and their Bluetooth and headset accessories, and further refinement of the hands-free "speaker phone" option. For members of the **Health and Scientific Communities**, the author recommends the objective reanalysis of all previous large-scale population studies that reported finding "no link between mobile phones and brain tumours", particularly from the perspectives of whether those "apparently negative or inconclusive studies" examined: (i) groups of

"heavy" mobile phone users followed for greater than 10 years; (ii) the occurrence of the key mobile telephony-associated brain tumours, namely acoustic neuroma (vestibular Schwannoma) and astrocytoma, in the study population; and (iii) the relationship between the side of the brain tumour and the "preferred side" for mobile phone usage among "heavy" users in whom a brain tumour developed. Further large-scale studies taking all of these perspectives into account are recommended and encouraged by the author in order to definitively validate or refute the conclusions of this paper. Finally, the aforementioned precautions should be **communicated to all at-risk persons** using mobile phones.

2. DISCLAIMER & CONFLICT OF INTEREST STATEMENT:

The Disclaimer denotes the responsibilities of the author and readers alike regarding the findings and recommendations of this work. The Conflict of Interest Statement discloses any specific relationship, financial or other, between the author and other persons, organisations or companies that can potentially detract from the independence and objectivity of this work.

Disclaimer:

Findings, conclusions and/or opinions communicated by the author of this paper are based on his **independent research**. This communicated material represents the **evidence-based conclusions** and opinions of the author alone, and do not necessarily reflect those of other individuals or third parties, including any employers. No institutional or company support or endorsement is intended by this communication, and **none was received** by the author for this work prior to this publication. Any recommendations made by the author should be independently and appropriately evaluated by the reader. The author accepts no responsibility and no liability for any negative actions of any person or group pertaining to the contents or recommendations of this paper.

It should be clearly understood that this paper in no way intends to defame or detract from the many positive contributions made by the Telecommunications Industry and its potential regulators. The author himself relies upon wireless technologies, although uses them with due caution (see safety tips, below). This paper should be regarded as a timely, objective and scientific marker for **immediately improving** the technological safety, while enhancing Public awareness and regulatory monitoring of these devices and their dissemination.

Conflict of Interest Statement:

The author declares that there is **no financial or other conflict of interest** in the research and communication of this unfunded and independent body of work.

3. AIMS & SCOPE:

The Aims and Scope of this work relate to the reasons this paper was written and its intended audience and impact.

Aims:

- To **scientifically and objectively review data** supporting or refuting a causal relationship between mobile phone usage and the occurrence of malignant brain tumours
- To explore the concept of **individual "susceptibility"** to developing a malignant brain tumour
- To provide **appropriate recommendations** based on the present evidence-based findings

Scope:

- The **General Public**
- Members of the **Telecommunications Industry**
- Members of the **Health and Scientific Communities** (including Government health regulatory officials)

4. HYPOTHESIS:

The Hypothesis represents the central claim being tested by this work.

The hypothesis of this work is that malignant brain tumours can be caused by "excessive" and prolonged mobile phone use.

5. INTRODUCTION:

The Introduction covers views expressed by the Popular Press and on the Internet regarding the topic of "mobile phones and brain tumours". Background information concerning electromagnetic radiation (EMR), and mobile phone and base station systems is also given in this section. Data regarding brain tumours and their rising incidence/occurrence are also presented. Finally, the concepts of mobile phone safety tips and brain tumour susceptibility are introduced here.

A. Popular Press and Internet:

- In early May, 2006, journalists for two leading Australian newspapers, namely *The Age* (May 12, 2006; Adam Morton & David Rood) and *The Australian* (May 13, 2006; Lisa Macnamara), reported that the top floors of a Royal Melbourne Institute of Technology building were closed after a **seventh worker** in as many years was **diagnosed with a brain tumour**. An official investigation found no causal link between the presence of **mobile phone towers on the roof** of that 17 storey building and this apparent "cancer cluster". It was reported that five of the seven affected occupants of the building worked on its top floor, immediately under the mobile phone transmission towers.
- In January, 2007, *The Jerusalem Post* (January 26, 2007; Judy Siegel-Itzkovich) reported that "an important study by **epidemiologists from five European countries**...has found a nearly 40 percent increase in a type of brain tumour among those who had used a **cell phone for a decade or more**." [This study by A. Lahkola, et al. (2007), subsequently published in the International Journal of Cancer, is reviewed in Section 7, below]. This press release goes on to state that: "The increase in **gliomas** [a very frequently malignant type of brain tumour], which was found to be statistically significant, was accompanied by a trend

showing that the brain tumour risk increased with years of use...The new retrospective study is based on the data collected in Denmark, Finland, Norway, Sweden and the UK and included **1521 glioma** cases and **3301 controls**." The article goes on to highlight the emerging concern among senior members of the US public health community regarding the need to put **precautionary measures in place** to limit non-ionizing radiation exposure particularly in **children**.

- Journalist Belinda Kontominas (*Sydney Morning Herald*, January 26, 2007, and with the *Telegraph*, London) added the following in her review of the same Lakhola et al. (2007) study reported by the Jerusalem Post: "Before separating out long-term users or looking at the different risks of developing tumours on the side where users held the phone, the scientists found no link between mobile use and gliomas. But when they focused only on those who had used a mobile for **10 years or more** they found that they were 39 per cent more likely than those in the general population to develop a **glioma on the side of their head where they held their handset**. Kontominas' article further states that: "The Chief Executive of the Cancer Council of Australia, Professor Ian Olver, said the study was not conclusive as it had only found the link when it looked at a much smaller sample. While any dangers of short-term use had been all but disproved, there might still be effects of long-term use, he said. "The best that I can say about this study is that it warrants a bigger study on the effects of mobile phones on long-term users.""
- An on-line article from www.EMF-Health.com (MSN, June 7, 2004) entitled "Brain Tumours: The Silent Killer" quotes a pre-eminent Australian **neurosurgeon**, **Dr Charlie Teo**, as follows: "When patients come in with a brain cancer, I often say to them, "your cancer was on the right side of the brain, it is in the area just above your ear, can you tell me if you feel that you have had more exposure than most people to mobile phones?" and I am surprised that most

people say, "yes I have used my phone continuously for the last seven years and it is always stuck to my ear on this side..." well that is where the cancer is."

- The Website "Accelerate Brain Cancer Cure" states that brain tumours are the **leading cause of death from childhood cancers** among persons up to 19 years, the second leading cause of cancer-related deaths in males ages 20-39, and the fifth leading cause of cancer-related deaths in females ages 20-39. In 2005, based on a US population of 287 million people, approximately 44 thousand people would be diagnosed with a brain tumour yearly in the US alone. This reflects an **annual brain tumour incidence of 15 people per 100,000 population** (i.e., In the US every year 15 new brain tumour patients should be expected to be diagnosed *in each group of 100,000 people*).
- As reported in the *Sun-Sentinel* in October 2005, lawsuits have been filed by attorneys representing individuals with brain tumours claiming they were caused by their mobile phone usage. Such suits are awaiting trial dates. Brain tumour patient Ms. Sharesa Price, through a Californian attorney, won the first law suit against cell phone companies. A popular press report relating to this is posted on YouTube and was also reported in a documentary entitled "Cell Phones: An Industry on Trial".
- An article written by an eminent British physicist, **Dr Gerald Hyland**, is quoted at www.cancer-health.org. The original article, entitled "Physics and Biology of Mobile Telephony", describes the **thermal effects** and the **non-thermal effects** of mobile telephony through both electromagnetic radiation and pulsed microwave radiation. Interestingly, the brain is recognised as an electrical organ. Per Dr Hyland: "To deny the possibility yet admit the importance of ensuring electromagnetic compatibility with electronic instruments by banning the use of mobile phones in aircraft and hospitals (a prohibition driven by concerns about non-thermal interference) seems inconsistent." In other words, if **cell phones interfere with aircraft and hospital electrical equipment** (even at quite a

distance), how can it be that they don't interfere with the electrical equipment of the head (i.e., the brain, when held for extended periods of time right next to this organ)?

- A registered supplier of equipment to the US Dept. of Defence, **Aegis Corporation**, produces **shielded equipment** that the company claims makes the use of wireless technology safer. Their Website details the risks associated with unshielded equipment. According to the information posted on their site, both **wireless (Bluetooth)** and **wired (unshielded) headsets** pose significantly **high amounts** of cell phone radiation exposure to users.

B. About electromagnetic radiation (EMR):

- **What is electromagnetic radiation?** The World Health Organisation (WHO) defines electromagnetic fields on its Webpages dedicated to the concerns regarding the increasing presence of this form of radiation. In essence, an **electromagnetic field** is comprised of two components, one being an **electric field** generated by **differences in voltage** and another being a **magnetic field** generated by the **flow of current**. The field propagates at the **speed of light** (300,000 kilometres per second or 186,000 miles per second) in **waves** of a certain **length** that oscillate at a certain **frequency** (number of oscillations or cycles per second). In the **electromagnetic range**, gamma rays given off by radioactive materials, cosmic rays, and X-rays are all dangerous to humans and other organisms because of the relatively **high energy** "quanta" (packets) they carry (**high frequency** or **short-wavelength** waves). Such rays lead to "dangerous radiation" (**ionizing**; i.e., with an ability to **break bonds** between molecules). **Mobile phone** systems also act in the **electromagnetic range** (sometimes referred to as "**microwave**" or "**radiofrequency**"), however, the frequency (energy "quanta") of the **longer-wavelength** waves associated with this

technology is lower (and therefore safer to humans) and regarded as "**non-ionizing**" (of "insufficient energy to break molecular bonds" -- however, this statement has been **contested in the scientific literature**; see Section 7 below).

- **What constitutes mobile phone technology?** Mobile phone technology, incorporating mobile phone **base stations** (antennae/transmission towers) and **mobile phone units** themselves, is associated with the production and propagation of electromagnetic radiation in the microwave range. The radio waves emitted by modern **GSM** (Global System for Mobile Communication; 900 & 1800 MegaHertz or MHz) handsets can have a **peak power** of up to 2 watts (2W), while other digital mobile technologies such as **CDMA** (Code Division Multiple Access; 800 and 1900 MHz) and **TDMA** (Time Division Multiple Access; 800 and 1900 MHz) have power outputs under 1 watt, levels generally regarded as being "safe" by most international governing authorities. The power generated by the handset can vary according to the amount of interference with the signal, a feature referred to as **Adaptive Power Control** (APC; see below).
- **Are cordless phones emitters of radiation?** As reported by Schuz and colleagues (*J. Schuz, et al., "Radiofrequency electromagnetic fields emitted from base stations of DECT cordless phones and the risk of glioma and meningioma (Interphone Study Group, Germany)"; Radiation Research (2006) Volume 166; pages 116-119*), one important source of low-level continuous exposures to radiofrequency electromagnetic fields (**RF EMFs**) is base stations of cordless phones that are located indoors, e.g., the Digital Enhanced Cordless Telecommunications (**DECT**) standard, operating at about 1900 MHz. These devices (both handset and base station) operate with 250 mW maximum power output, with their **base stations continuously emitting pulsed radiofrequency radiation** irrespective of the handset being in operation or not, and often with the base station being **kept close to the bed head** at night. Measurements of these base stations' electromagnetic fields reveal power densities (defined below)

between 4 and 170 mW/m2 for distances up to 3 metres from the base station (**maximum permitted by law is 450 mW/m2**); these fields are **present long-term** and this magnitude is comparable to power densities measured in residences in the main beam of nearby cell phone base station antennae or in the vicinity of broadcast towers.

- **What about "walkie-talkies" or "CB (Citizens' Band) radios"?** Unfortunately, these devices emit at **relatively very high power outputs** (e.g., 3-4 W) compared to mobile and cordless phones, even though their frequency bands may be lower. They are considered to be the **worst offenders** of all the mainstream hand-held "wireless" two-way communication devices in terms of electromagnetic radiation exposure. They are **widely used** by our emergency services, armed forces, construction sites, trucking industry airports and rural communities. **Children** use them without any knowledge of the potential dangers associated with such devices. To view their electromagnetic "plumes" visit the following URL: http://www.ortho.lsuhsc.edu/Faculty/Marino/EL/EL10/Levels.html
- **What is the Inverse Square Law and how is it relevant to mobile telephony?** The intensity of electromagnetic radiation varies with the distance from the source according to the Inverse Square Law. This means that the radiation's intensity is inversely proportional to the square of the distance between the source and the exposed object. Applying this concept to mobile telephony, the **further one holds a mobile phone from the head, the less the (intensity) exposure of the head and brain** to electromagnetic radiation. This accounts for the relative safety of a **hands-free speaker phone** mode and, **in cars**, the use of **hands-free car speaker/microphone kits** (where the **car's roof** acts as the **antenna**) instead of the mobile phone itself or an unshielded headset. Regarding car speaker kits for hands-free mobile telephony, The Australian Government Environmental Protection Agency states that due to the increased separation between the antenna

(now the car roof) and the user's head, exposure to electromagnetic radiation is **reduced by about 100 times** when compared to normal mobile phone use.

- **What effects can mobile phones have on body tissues?** The potential effects of mobile phone-associated electromagnetic radiation on tissues include "**thermal**" and "**non-thermal**". **Thermal effects** are due to tissues being **heated** by rotations of molecules induced by the electromagnetic field. In the case of a cell phone, the **head/ear surfaces** close to the phone may be induced to heat. This heating has been thought to cause molecules within cells called "**heat-shock proteins**" to become activated and repeated activation of such proteins by microwaves/electromagnetic radiation can lead to cellular events culminating in cancerous transformation of the cell (*C. Jolly & R.I. Morimoto, "Role of heat-shock response and molecular chaperones in oncogenesis and cell death"; Journal of the National Cancer Institute (2000) Volume 92; pages 1564-1761*). **Non-thermal effects** are due to low-frequency (but long-term) "**pulsing**" of the carrier signal. Non-thermal effects from microwaves similar to those generated by mobile phones have been implicated in **genetic (DNA) molecule damage**. This remains contentious and is elaborated in Section 7, below.
- **What is the Specific Absorption Rate (SAR)?** The Specific Absorption Rate (SAR) measures the **rate at which radiation is absorbed** by the human body. For the **head**, the Federal Communication Commission (**FCC**; USA) has set a **SAR of 1.6 W/kg**. The **SAR is 0.08 W/kg** averaged **over the body** as defined by the International Commission on Non-Ionizing Radiation Protection (**ICNIRP**) guidelines. The averaging volume (e.g., "head" versus "whole body") must be specified in order to make meaningful (and less ambiguous) interpretations of stated SAR values between emitters and between receivers. Note that the **human head weighs** about **9 pounds or 4 kg, while the average adult male weighs around 180 lbs or about 80 kg)**. A SAR of **4 W/kg** is associated with a **1 degree temperature rise** in humans. Although current mobile phones operate with power

outputs that fall within "acceptable government-set limits", local thermal or heating effects on the head may still be quite apparent to users after **prolonged usage**. The underlying brain is also heated as depicted on an Australian Government Webpage. In mobile telephony, the **specific absorption rate or SAR depends on several factors**, including the **antenna** type and position, the **distance** between the phone and the head, and the **power output** of the phone (which through "adaptive power control" can change during the conversation; see below).

- **What is Adaptive power control (APC) and how is it relevant?** The level of electromagnetic radiation a user's head may be exposed to during mobile phone telephony **can vary** during the conversation, according to the **variable power output of the phone**. The operator's network controls and adjusts the output power of each connected mobile phone to the lowest level compatible with a **good signal quality**. This is obtained by scaling the power from the maximum (1 or 2 W at 1800 MHz and 900 MHz, respectively) down to as low as 1 milliW. Such "adaptive power control" **takes place continuously**, with the selected power level depending on several factors, including the **distance** from the base station, the presence of **physical obstacles** (such as tall buildings), whether the phone is used indoors or outdoors, and "**handovers**" between linked base stations (during handovers, the output power of the phone is generally set to the highest level; *S. Lonn, et al., "Output power levels from mobile phones in different geographical areas; implications for exposure assessment"; Occupational and Environmental Medicine (2004) Volume 61; pages 769-772*). In other words, deep in a building or in a moving elevator, the handset's power output increases temporarily in order to pick up a base-station's signal so that the phone users can continue to communicate effectively. During this **higher power transmission**, the user's head is subjected to more than the usual amount of electromagnetic radiation from the mobile phone.

- **What is magnetic flux density?** The term magnetic flux is used to describe the field that results when a magnetic field is present in any material. The unit of magnetic flux is the Weber (Wb), being that flux which, when linked with a single turn, generates an electromagnetic field of 1 volt in the turn, as it decreases uniformly to 0 in 1 second. When the magnetic flux (in Wb) is averaged over an area of a square metre, the **magnetic flux density** is known. The unit of magnetic flux density is the **Tesla (T)**, being Wb/square metre. As stated by Petrucci (*N. Petrucci, "Exposure of the critically ill patient to extremely low-frequency electromagnetic fields in the intensive care environment"; Intensive Care Medicine (1999) Volume 25; pages 847-851*), "the value of **0.20 microTesla** of magnetic flux density has been empirically defined as a **safety threshold** for exposure of the whole body to extremely low-frequency electromagnetic fields, considering that **nervous tissue has the lowest tolerance**."
- **What is magnetic power flux density?** The rate of flow of electromagnetic energy per unit area is used to measure the amount of radiation at a given point from a transmitting antenna. This quantity is expressed in units of Watts per square meter (**W/m2**) or milliWatts per square cm (**mW/cm2**). The **maximum exposure level** for members of the Public exposed to electromagnetic radiation at 900MHz is **0.45 W/m2**. This figure can be compared with the amount of heat radiated by the human body at room temperature of about 2W/m2. Although this level of permitted exposure to mobile telephony-related electromagnetic radiation is low, it is nonetheless **constant** in our environment, and **compounded** to by the use of multiple other wireless technologies at any given time.
- **What about "exposure" to electromagnetic radiation?** Exposure to the radiation emitted from mobile phones varies according to several factors, including: (i) the **power output** of the phone at any given time; (ii) the **type of phone** and the type and location of its **antenna**; (iii) the **distance** between the head and the telephone; (iv) a **young child** user's versus an adult user's head; (v)

urban versus rural location during usage; (vi) the **pattern of usage**, i.e., the length and number of calls.

C. Mobile phones and base stations:

- **The basics of mobile phone technology** are detailed on an Australian Government Website maintained by the Australian Radiation Protection and Nuclear Safety Agency (ARPNSA).
- **Brief history of mobile phone systems (Sweden):** Mobile phones and their networks were **first deployed in Sweden in 1981** via the Nordic Mobile Telephone (**NMT**) System (**analogue**; 450 MHz bandwidth; 1st Generation or 1G); mass deployment was present in Sweden by 1985. The analogue 900 MHz system started there in 1986, but was closed in Sweden by 2000. The **digital system** (Global System for Mobile Communication; **GSM**) started in 1991, representing the second generation of mobile phone systems, or "**2G**". The **latest system** currently in mass deployment is based on adaptations of **CDMA** and **TDMA** (Code and Time Division Multiple Access, respectively; 800-1900 MegaHertz ;"3G").
- **About providers and users:** Mobile phone technology consists of **two main components**, namely, the **provider** and the **user**. On the side of the **provider** are the **base stations** (the antennae on the earth's surface which communicate with the phones). On the side of the **user** are the **mobile phones themselves**. **Base stations emit** electromagnetic radiation **continuously**, and at far greater power than mobile phones which emit electromagnetic radiation continuously only during calls. At all other times, i.e., between calls or "at rest" (with the "screen asleep" but the power still on), **mobile phones** emit a **regular pulse of electromagnetic radiation** in order for base stations to continuously keep track of the geographic position of the phones in their "cellular network". Modern 2nd

generation (2G) antennae are associated with transmitter powers of 20 - 100 Watts, although the latest 3rd generation (3G) antennae use less power, on average 3 Watts in urban areas. In **rural areas**, the **base station power output is much higher** because of the vast areas needed to be covered between base stations placed in remote regions.

- **Why "Cellular"?** The mobile phone system is referred to as "**cellular**" because, owing to the limitation of available radiofrequencies, it is **divided up into cells**. In the **GSM system,** cells consist of **base station antennae** emitting at specified frequencies, and a **group or network of users** whose mobile phones communicate at those **specified frequencies**. Geographically adjacent cells have different frequencies to prevent interference. The more users in a cellular network using their phones simultaneously, the greater the antenna power output. In the **CDMA system**, all cells use the same radiofrequency spectrum and interference is prevented by transmitting a code which repeats at constant time intervals. These time intervals vary from one base station to another and thus enable interference to be prevented. Transmitted power levels are kept to the minimum necessary to maintain good communications.
- **About "dead spots":** In general, base station antennae must be **elevated** and located **clear of physical obstruction** to ensure wide coverage and reduce the incidence of "dead spots". These "**dead spots**" represent areas where there is **no signal** due to **obstruction** from, say, tall buildings. Such "dead" regions are covered by "**microcells**" whose antennae have much lower power outputs of around 1 Watt, but are **densely concentrated** in urban areas. In general, the radiation from mobile phone antennae is beamed horizontally at the horizon with a slightly downward tilt which causes the **maximum exposure** to occur at a distance of **about 100 metres**.
- **The urban sprawl:** As technology progresses and data demands have increased on the mobile networks, the **numbers of towers has increased tremendously**,

with little or no effort being made between companies to share such towers. Smaller but more numerous antennae throughout our urban environments have allowed for clear cell phone reception within moving elevators, in the centres or even basements of large buildings, and other previously "reception-poor" locations. The ability of a **cell phone user to be "found" by a base station in an instant at almost any location** on earth should be startling, and indicative of the widespread, now almost all-pervasive generation and propagation of mobile telephony-related electromagnetic radiation via microcellular networks.

D. About brain tumours:

- The **www.brain-surgery.us** Website contains pages dedicated to providing information about brain tumours. In order to avoid repeating that information on this paper, visit any of the links below for further information and images regarding brain tumours. Note that, more recently, well conducted clinical studies have shown a significant link between long-term mobile phone usage and two classes of brain tumours, namely, **acoustic neuroma** (aka **vestibular Schwannoma**) and **glioma** (in particular, the malignant forms of "**astrocytoma**").
    - For facts about brain tumours in general, visit this link: **http://www.brain-surgery.us/brain_tumour.html**
    - For images and information concerning "**acoustic neuroma**" (aka vestibular Schwannoma), visit this specific link: **http://www.brain-surgery.us/Schwannoma.html**
    - For images and information concerning **astrocytoma** (the typical malignant type of "glioma"), visit this specific link: **http://www.brain-surgery.us/glioma.html**

E. About the rising incidence of brain tumours:

- In 1990, Grieg and colleagues (*N.H. Grieg, et al., "Increasing annual incidence of primary malignant brain tumours in the elderly"; Journal of the National Cancer Institute (1990) Volume 82; pages 1621-1624*) reported a **7% - 23.4% annual percentage rate increase** in the diagnosis of malignant brain tumours in persons greater than 75 years of age, over the years **1973-1985**. The reported incidence among **younger persons varied little** over the same period of time, suggesting a true incidence increase in the older population. This time frame **predates** the introduction of widespread mobile phone technology (which was beginning to take off widely first in Sweden in the mid-80's), and the increase may partly have been explained by the **more extensive use of imaging technology** (computerized tomography or **CAT scanning**) during that time period. However, a true increase in incidence could not be ruled out but, during the time period studied by this particular group, was likely not due to mobile phone technology.
- In 1998, Smith and colleagues (*M.A. Smith, et al., "Trends in reported incidence of primary malignant brain tumours in children in the United States"; Journal of the National Cancer Institute (1998) Volume 90; pages 1269-1277*) reported a **35% increase** in the incidence of **primary malignant brain tumours** among **children** during the period **1973-1994**, with a step-like increase noted in the mid-1980s. The authors suggested this increase was likely the result of better (or earlier) **radiological detection and/or reporting** trends concerning brain tumours in children during this time. Again, a true increase in incidence from some other yet-unidentified cause could not be ruled out.
- Researchers in Sweden looked at the incidence of childhood malignant diseases in that country between the years **1960 - 1998**. As reported by Dreifaldt and colleagues (*A.C. Dreifaldt, et al., "Increasing incidence rates of childhood malignant diseases in Sweden during the period 1960-1998"; European Journal*

of Cancer (2004) Volume 40; pages 1351-1360), significant changes were found. Of the tumours of the **brain**, an **increasing incidence of between 2-4%** per year was found; the study included data from over 2,500 children with brain tumours. They concluded that changes in **diagnostic criteria** and better **diagnostic tools** may have contributed to these results. However, an argument against this conclusion is that their study found that **lower grades of malignant brain tumours** had increased during this time **over and above** the **unchanged incidence of higher grade malignant brain tumours** in the same population of children. As a result, a **true increase in incidence** (i.e., not related to better detection and reporting trends) could not be ruled out.

- Further worrisome data was reported by Jukich and colleagues in 2001, who studied data from over 16,000 brain tumour patients. This group (*P.J. Jukich, et al., "Trends in incidence of primary brain tumours in the United States, 1985-1994"; Neuro-Oncology (2001) Volume 3; pages 141-152*) found when analysing the type of brain tumour (histopathological classification) and the age-group of brain tumour patients that the **incidence of high-grade brain tumours had increased by over 5% per year in patients aged 20-64 years**, but the incidence of **low-grade brain tumours** in persons in this age group had **decreased** during this time by the same amount annually. They also found that the incidence of **nerve sheath tumours increased almost 6%** per year in males during 1985-1994. Again, no specific cause for this increase was suggested by these authors, however they concluded: "Taken together, the results obtained in this study **do not support diagnostic changes as the full explanation** for changes in incidence over the last decade."
- Nelson and colleagues examined the incidence of **acoustic neuroma** (vestibular Schwannoma) in the UK population between 1979-2001. They noted that cell phone usage commenced in the UK in 1985, with a sharp rise in the registered number users between 1998 onwards. In their paper (*P.D. Nelson, et al., "Trends*

in acoustic neuroma and cellular phones: Is there a link?"; Neurology (2006) Volume 66; pages 284-285), compared with the numbers of these tumours diagnosed in 1979, a greater than **three-fold rise** in cases was found by 1997, however only a **2.5 fold increase by 2000** when compared with the 1979 data. From this data, despite the increased incidence or detection rate of this kind of brain tumour, the increases **preceded** the widespread use of cell phone technology in the US, and the authors concluded that "the trends in acoustic neuroma are most likely explained by **changes in reporting and diagnosis**. However, given the **long latency** [i.e., the approximate 10-year time course for such solid tumours to grow and manifest neurologically], we are still at an **early stage** in observing possible health effects associated with cellular telephones."

- A large study looked at a **change in death rates** from brain tumours among mobile phone users in Switzerland from 1987-2002, compared with brain tumour death rates in Switzerland from 1969-1987. The authors (*M. Roosli, et al., "Cellular telephone use and time trends in brain tumour mortality in Switzerland from 1969 to 2002"; European Journal of Cancer Prevention (2007) Volume 16; pages 77-82*) concluded that **mobile phone use was not a strong risk factor** in the **short term** for **mortality** from brain tumours. Mobile phones were introduced into Switzerland in 1992. However, they recognised the **obvious limitations of their study**, namely, that it: (i) focused on death rates from brain tumours rather than brain tumour incidence rates; (ii) did not look at brain tumour histopathological subtypes (known from other studies to have marked changes in incidence rates over time; see above); (iii) didn't perform any subgroup analysis on so-called "heavy" and/or "long-term" cell phone users; (iv) only had reached the cusp of long-term usage (10 years), whereas following tumour trends out to 15-20 years (to around 2008-2012) seems more likely to yield definitive results.
- The **Central Brain Tumor Registry of the United States** (CBTRUS) has recorded an approximately 15% increase in the incidence of primary brain

tumours between the period 1998-2002 compared with the period 1990-1994. This increase has all been in the "MRI" age of the USA, a fact that suggests that the increase is not due to "better detection" or "earlier reporting", since MRI was widely available in the US during this period of time. Visit the following URL: http://www.cbtrus.org/reports/reports.html

F. Look's good but is it safe?

(i) Safety tips: The following important points regarding mobile phone safety should be kept in mind:

- **Bluetooth ear-piece devices are NOT safe**. Microwaves generated by the mobile phone are wirelessly transferred and **directly transmitted** into the ear canal and surrounding head region via the coupled blue tooth device.
- **Wired ear-pieces are NOT safe** unless they are specifically shielded against electromagnetic radiation. Wearing an ear-piece connected by a wire to a mobile phone in essence **converts the user's head into an antenna** for the base-station.
- **Home-based cordless phones** do not emit as much electromagnetic radiation as conventional mobile phones, however they are **NOT to be regarded as being safe** owing to the **longer usage time** (typically cheaper calling rates) associated with home-based calling plans. Using such phones for less time and on "speaker-phone" mode with the **cordless phone held at least 20 cm from the head** is a safer alternative to holding them close to the side of the head.
- **"Walkie-talkies" are NOT safe**. They emit very high levels of electromagnetic radiation, up to **50 times more than a mobile phone**.
- Keeping a **mobile phone close to one's head overnight is NOT safe**. Even "at rest", the mobile will **regularly emit a pulsed microwave signal** to its closest base station in order for the mobile phone's position to be tracked in order to maintain its expected service.

- **A regular landline IS safe**, in fact this remains one of the safest forms of electronic verbal communication.
- Using the **"speaker phone" option** on a mobile phone, with the phone **held at least 20 cm from the head is a safer alternative** (inverse square law for radiation fall-off), however, this naturally compromises the privacy of the communication to some extent.
- Using a mobile phone via **hands-free car kit** (where the car speakers and car microphone are used instead of the mobile phone being held to the side of the head) **IS safe**. Here, the **car roof acts as the antenna**, and the user's head is at an acceptable distance from both the roof and the phone (inverse square law for radiation fall-off).
- A **child's brain** is structurally developing well into adolescence, has a greater relative water content and lower volume compared with an adult's brain, and subject to more "plasticity" (structural and functional reprogramming) at a microscopic level. It is logical to expect that exposing a child's brain to cell phone radiation is likely to cause cellular damage that, in due course, may lead to brain cancer. **Children should NOT use mobile or cellular phones unless in an emergency**.

(ii) About Dr George Carlo:

This section is adapted from an apparently well researched article written by **Don Maisch** and published in the Journal of the Australasian College of Nutritional and Environmental Medicine in 2001 (*D. Maisch, "Mobile phone use: it's time to take precautions"; Journal of the Australasian College of Nutritional and Environmental Medicine (2001) Volume 20, pages 3-10*).

- As a result of a widely publicised court case in the early 1990s in America, where it was claimed a fatal brain tumour was caused by extensive mobile phone use, the Cellular Telephone Industry Association (CTIA) set up the **Wireless Technology Research (WTR) research program** in 1993. This research program was funded to the tune of $27 million to identify and solve any problems concerning consumers' health that could arise from the use of these phones. A well-recognised scientist, **Dr George Carlo**, was invited by the CTIA to head the WTR's research program. However, in **February of 1999**, George Carlo, who had previously maintained the Industry line that mobile phones were safe, stunned the industry with a report that he presented to the annual convention of the CTIA in California.
- Specifically, Dr. Carlo reported to the industry convention that, based on his research:
    - The **rate of death from brain cancer** among handheld phone users was **higher** than the rate of brain cancer death among those who used non-handheld phones that were away from their head;
    - The **near-field electromagnetic plume** of seven or eight inches around the antenna of the cell phone caused **leakage in the blood brain barrier**, a key anatomical and physiological regulator of brain "equilibrium" or "homeostasis";
    - The **risk of acoustic neuroma** (vestibular Schwannoma), a tumour of the nerves for balance and hearing, was 50% **higher** in people who reported using cell phones for 6 years or more; moreover, that relationship between the amount of cell phone use and this tumour appeared to follow a **dose-response curve**;
    - The risk of **rare neuroepithelial tumours** on the outside of the brain was more than doubled, a statistically significant risk increase, in cell phone users as compared to people who did not use mobile phones.

- Importantly, Dr Carlo stated that **appropriate steps were not being taken** to protect consumers during the time of uncertainty about safety and that Industry continues to miss a valuable opportunity by dealing with these public health concerns through politics, creating illusions that more research over the next several years would help consumers today, while **falsely claiming that regulatory compliance equated to safety**. Dr. Carlo also said that he was alarmed that sectors of the Industry had **ignored the scientific findings** suggesting potential health effects, have repeatedly and falsely claimed that wireless phones are safe for all consumers including children, and have created an illusion of responsible follow-up by calling for and supporting more research.
- Dr Carlo has been regarded as a **key whistleblower**, and according to a recent on-line report, since the public communication of his findings, Dr Carlo "has been threatened, physically attacked, defamed, and his house mysteriously burned down." George Carlo subsequently published a book ("Cellphones: Invisible Hazards of the Wireless Age") about his alarming experiences as part of the Wireless Industry.

G. A matter of susceptibility:

- **About "Exposure" and the "Exposed":** In models of cancer, there are two fundamental components. One is the "**exposure**" (the "**source**" - e.g., ultraviolet radiation, a chemical carcinogen such as in asbestos or cigarette smoke, or x-rays and gamma rays). The other is the "**exposed**" (the "**recipient**" - e.g., humans and the response they mount to the exposure). The contribution that each of these two components makes to the initiation and perpetuation of cellular processes that culminate in "cancer" **can vary between places** (since the type and degree of exposure may vary from one geographic location or environment to another) and **between people** (since **genetic differences** between humans can influence the

ways in which those humans respond to the "exposure"). Variation in the type, length and strength of the exposure or in the response to the exposure is referred to as "**susceptibility**". In other words, an individual may be more susceptible to forming a cancer if exposed to greater duration and/or strength of, say, some form of radiation; here the "exposure" has varied. Alternatively, two individuals exposed to the same amount and type of radiation, say from cell phones, may not respond from a brain cancer perspective at exactly the same time and in exactly the same way to the "exposure". It is plausible to expect that genetic differences between individuals that govern differences in the ways the brain tissues of those individuals are "hardwired" at cellular and subcellular levels likely account for the variability of the response to low-level exposures. Naturally occurring variations in genes (**polymorphisms**) regulating **heat-shock protein production** and **oncogene** (pre-cancer gene) **expression** may be examples of why certain individuals respond differently to certain tissue stressors than others. Genetic polymorphisms also frequently account for varying drug "effects" and drug "side-effects" between individuals given the same doses of the same medications.

- **Anecdotal "occupational exposure" reports:** There are many anecdotal reports (i.e., **scattered reports** of **small numbers** of individuals with certain conditions) regarding **occupational electromagnetic radiation exposure** and the occurrence of **brain tumours** in those persons (e.g., radar workers or cell phone testers and programmers). Such reports suggest that individuals in these professions may be **more susceptible** to developing brain tumours. For an example of these types of reports, refer to Richter and colleagues (*E.D. Richter, et al., "Brain cancer with induction periods of less than 10 years in young military radar workers"; Archives of Environmental Health (2002) Volume 57; pages 270-272*) and Brautbar (*N. Brautbar, "Rapid development of brain tumours in 2 cellular phone testers"; Letter in Archives of Environmental Health*). Another example is a report of a brain cancer cluster in a University building with mobile phone towers on its

roof. No solid scientific value can be placed on anecdotal reports such as these, despite their "suggestive" implications.

- **"Microwave Sickness Syndrome":** Some individuals seem to be more susceptible to a so-called "microwave sickness syndrome", where long term low level exposure to high-frequency electromagnetic fields may result in a number of **symptoms such as headache, fatigue, sleep disorder, and memory impairment**. In a thoughtful and apparently well constructed study of the presence of features of a "microwave sickness syndrome" among 365 subjects in urban and rural areas in Austria, Hutter and colleagues found that the presence of symptoms such as **headache and difficulties in concentrating** (but not sleep disturbance or fatigue) showed a significant association with the **"dose" of microwave exposure from base stations**. This dose-dependent association was found not to be attributable to subjects' fear of health effects from these sources. The confounding effect of the copresence of anxiety and depression could not be ruled out in this study, however, this possibility was made less likely by the fact that the presence of "disturbed sleep" and "fatigue" as symptoms (more frequently noted in persons with psychological disorders) were found to be similar between higher and lower base station radiation "dose" groups (*H.P. Hutter, et al., "Subjective symptoms, sleeping problems, and cognitive performance in subjects living near mobile phone base stations"; Occupational and Environmental Medicine (2006) Volume 63; pages 307-313*). Contrarily, Rubin and colleagues carried out a well constructed double-blind, randomised case-control study of 120 people (60 of whom reported often getting "headache-like symptoms" within 20 minutes of using a standard GSM mobile phone; and the other 60 of whom denied such symptoms) exposed to 50 minutes of each of the following: A 900 MHz GSM mobile phone signal, a non-pulsing carrier wave signal, and a sham condition with no signal present. They concluded that "**no evidence** was found to indicate that people with **self-reported** sensitivity to mobile phone signals are

able to detect such signals or that they react to them with increased symptom severity." However, they noted among persons who self-reported being sensitive to mobile telephony, symptom severity did increase during exposure (even to a sham signal). As the authors state: "Indeed, for some they were so severe that exposures had to be stopped early or the participants withdrew from the study". This finding was attributed to a so-called **"nocebo" effect** (an expectation of bad or "adverse" symptoms in the presence of some perceived bad or "adverse" effect or exposure; *G.J. Rubin, et al., "Are some people sensitive to mobile phone signals? Within participants double blind randomised provocation study"; British Medical Journal (2006) Volume 332; pages 886-891*).

- **Does where one lives matter?** In 2001, Lonn and colleagues recorded the average power output of mobile phones in Sweden over the period of one week in different geographical areas of that country, then using a standard GSM system operating at 900 MHz and 1800 MHz frequency bands (the same as those used internationally (*S. Lonn, et al., "Output power levels from mobile phones in different geographical areas; implications for exposure assessment"; Occupational and Environmental Medicine (2004) Volume 61; pages 769-772*). They found that in **rural areas** (where base stations are sparse -- i.e., greater distances between mobile phones and the nearest base station), mobile phones were **twice as likely to be operating at their highest power output** and seven times less likely to be operating at their lowest power output compared to mobile phones in urban areas. Following up on this issue, in 2005, Hardell and colleagues (*L. Hardell, et al., "Use of cellular telephones and brain tumour risk in urban and rural areas; Occupational and Environmental Medicine (2005) Volume 62; pages 390-394*) reported a case-control study of nearly 3000 people in Sweden looking at the incidence of **brain tumours** between **city-dwellers (urban)** and **country-dwellers (rural)** between the years 1997 and 2000. The startling finding was a **3-to-4-fold increase in the incidence of brain tumours in the rural population**

compared with the urban population among persons using digital phones **"heavily" for greater than 5 years** (akin to a **"dose-dependent" effect**). At the time they did not have enough follow-up data to meaningfully analyse differences in the incidence of brain tumours among rural compared with urban populations using digital phones for greater than 10 years. They suggested a possible reason explaining this difference**: increased power output** from mobile phones in rural areas, owing to the presence of "adaptive power control" (see above) capability in digital mobile phones and the fact that base stations were fewer and further between in rural areas compared with urban areas. Is it possible that mobile phones were being used more in rural areas than urban areas? Unlikely given the findings of Lonn and colleagues in a Swedish study that found that mobile phone usage in urban areas (175,000 hours) was seven times that recorded in rural areas (25,000 hours; *S. Lonn, et al., "Output power levels from mobile phones in different geographical areas; implications for exposure assessment"; Occupational and Environmental Medicine (2004) Volume 61; pages 769-772*).

- **Can exposures other than electromagnetic radiation account for increased tumour rates in the rural farming population?** Ruder and colleagues surveyed approximately 2000 people in Midwestern non-metropolitan regions in a comprehensive case-control study (798 cases with brain cancer; 1175 controls without brain cancer) designed to determine whether environmental exposures to pesticides, farm animals, gasoline and solvents could account for brain tumour rates being higher in farming populations compared with non-metropolitan, non-farming populations. The study, carried out on behalf of the **US National Institute for Occupational Safety and Health** as part of the Upper Midwest Health Study, also considered exposures to television, dental x-rays, smoking, and alcohol, but did not specifically examine the role of exposure to mobile phone electromagnetic radiation. Overall, the authors found no increased risk of brain cancer associated with farm residence (compared with non-farm, non-

metropolitan residences with populations < 250,000). The authors also found no association of brain cancer with broad categories of pesticides and other farm-related characteristics. Although Ruder and colleagues did not compare these rates and exposures with those observed in urban residences (with populations > 250,000), their findings suggest that farm-related pesticide, animal, gasoline, and solvent exposures do not increase the risk of brain cancer. The implication is therefore made that if brain cancer rates are indeed higher in rural populations, then the cause is something other than those exposures studied by Ruder and colleagues (*A.M. Ruder, et al., "The Upper Midwest Health Study: A case-control study of primary intracranial gliomas in farm and rural residents; Journal of Agricultural Safety and Health (2006) Volume 12; pages 255-274*).

- **Susceptible children:** The question regarding whether children are more susceptible to any harmful effects of electromagnetic fields has not been definitively answered, however, there are good reasons to suspect that in due course, the answer may be "yes". As indicated by Kheifets and colleagues (*L. Kheifets, et al., "The sensitivity of children to electromagnetic fields"; Pediatrics (2005) Volume 116, pages 303-313*), in children: radiofrequency radiation **absorption and penetration are greater** owing to their **smaller head size** and **thinner tissue thicknesses**; a **longer lifetime of exposure** should be expected than adults, because of the trend of mobile phone use in even the very young child population; and their **brain tissue is more conductive** than that of adults owing to a **higher relative water content** and ion concentration. Tumours such as meningiomas, astrocytoma, and cavernous malformations are known to develop in the central nervous system of adults and children who have had for one reason or another (e.g. for brain astrocytoma or arteriovenous malformation), often many years previously, brain radiation using more powerful ionizing sources (conventional whole brain radiation therapy).

6. METHODS:

The Methods outlines the approach used by the author in researching and writing this paper.

Between December 2006 and February 2008, the author personally reviewed over 100 sources of information extracted from the medical literature (PubMed and Medline searches using keywords and combinations such as "Brain Tumour", "Cell Phone", "Mobile Phone", "Base Station", “Electromagnetic Field”, "Electromagnetic Radiation", and "Radiofrequency Radiation") and the Internet and popular Press (Google and MSN searches using the same keywords and combinations). Important references are italicised throughout this paper.

7. RESULTS:

The Results section summarises the data reviewed by the author such as population-based studies, laboratory studies, and critiques of those studies.

A. Clinical Studies:

(i) "POSITIVE" CLINICAL STUDIES - i.e., those studies that **show a statistically significant association** between cell phone usage and brain tumour development:

- A recent "**meta-analysis**" (a broad statistical review of the scientific literature regarding a particular topic) carried out by Swedish oncologist and cancer epidemiologist **Lennart Hardell** has been published on the topic of cell phones and brain tumours. Hardell and colleagues conclude "Results from present studies on use of mobile phones for **10 or more years** give a **consistent pattern of increased risk for acoustic neuroma and glioma**. The risk is higher for **ipsilateral exposure** (i.e., cell phone use preferentially on the same side as the eventually diagnosed brain tumour)." (*L. Hardell, et al., "Long-term use of cellular phones and brain tumours: increased risk associated with use for >= 10 years"; Occupational and Environmental Medicine (2007) Volume 64: pages 626-632*). While Hardell's group was unable to show that cell phones were risk factors for salivary gland cancer (glands located around the ear and jaw region of the head and potentially exposed to cell phone radiation), Non-Hodgkin Lymphoma (NHL), and testicular cancer (testicles exposed to cell phone radiation in men who wear cell phones close to the groin), the same group has **consistently found** an increased risk for brain tumours in their publications since 2000 (*L. Hardell, et al., "Tumour risk associated with use of cellular telephones or cordless desktop telephones"; World Journal of Surgical Oncology (2006) Volume 4: 74*).

- In 2000, Hardell and coworkers reported that among brain tumour patients regularly using mobile phones the **temporal, occipital and temporoparietal regions** of the brain showed **increased risk** of developing a brain tumour on the same side of their head as the preferred side for mobile phone usage. These anatomical areas represented **immediately adjacent parts of the brain** with the highest exposure to the **near-field electromagnetic radiation plume** during a phone call using a cell phone. This was relatively early data and involved relatively low numbers of persons (**209 "cases"** with brain tumours diagnosed in Sweden between 1994 & 1996; and **425 "controls"** without brain tumours), overall regarded as preliminary but suggestive work (*L. Hardell, et al., "Case-control study on radiology work, medical x-ray investigations, and use of cellular telephones as risk factors for brain tumours"; Medscape General Medicine (2000) Volume 2: E2*).
- In 2002, Hardell's group looked at data from regional cancer registries that had recorded **588 "cases"** in three regions of Sweden living with malignant brain tumours (patients with tumours diagnosed between 1997-2000; a further 393 people who were eligible as "cases" in fact died while the study was being organised). **581 "controls"** (persons without brain tumours matched against "cases" for gender, age, and geographical site of residence) were designated by the researchers. A very comprehensive questionnaire was included as part of the study, assessing for exposure to various potential environmental, personal and work-related cancer-causing agents (carcinogens such as asbestos, cigarettes, pesticides, organic solvents, oils, ionizing radiation, and electromagnetic radiation). Detailed questions were asked concerning cell phone usage (cell phone make/type to ascertain analogue versus digital, preferred ear, hours per day, years of usage, alternative use of in-car phone-speaker kit, and so forth). Only when the authors ascertained **which side of the head was favored for cell phone** usage, and **which side of the head the tumours developed** among cases did they find

that the use of a digital or analogue phone yielded **significantly increased risks** (by 1.5- to 2-fold) of developing a brain tumour on the same side of the head as that preferred for cell phone use *(L. Hardell, et al., "Case-control study on the use of cellular and cordless phones and the risk for malignant brain tumours"; International Journal of Radiation Biology (2002) Volume 78; pages 931-936*). Regarding **astrocytomas** specifically, the risk was highest using **analogue** phones (greater power output than their digital counterparts). This was also reported independently at the time by a Finnish study (*A. Auvinen, et al., "Brain tumours and salivary gland cancers among cellular phone users"; Epidemiology (2002) Volume 13; pages 356-359*). A **dose-dependence** (i.e., increased hours of daily usage resulting in increasing numbers of tumours) was **not proven** in the Hardell group's study which was limited by relatively small numbers. However, its findings again raised concerns.

- In 2003, Hardell's group looked at further data that was available from regional cancer registries in Sweden, this time assessing **1429 "cases"** with brain tumours, and **"1470" appropriately matched "controls"** without brain tumours. In this expanded study, with more than twice the numbers of their previous study, use of all three phone types (**digital, analogue and cordless**) was associated with **significantly increased risk** (almost **2-fold**) of developing an astrocytoma (malignant brain tumour) on the same side of the head as the preferred side for cell phone use. The location of significance for astrocytoma was the **temporal lobe** for persons using analogue cells phones (higher electromagnetic radiation/higher power output from this type of phone), and this risk and location association, statistically significant, appeared to **increase with duration of usage over 10 years** (akin to a **"dose-dependent effect"**). **Analogue** phones were also significantly associated with increased (four-fold) risk of the development of **acoustic neuroma** in this study (*L. Hardell, et al., "Further aspects on cellular*

and cordless telephones and brain tumours"; International Journal of Oncology (2003) Volume 22; pages 399-407).

- Using information obtained from Cancer Registries in Uppsala/Orebro and Linkoping, Sweden, Hardell's group surveyed **317 malignant brain tumour "cases"** (recorded in those registries between 2000 and 2003 and not part of their previous studies) and **692 appropriately matched "controls"** (*L. Hardell, et al., "Case-control study of the association between the use of cellular and cordless telephones and malignant brain tumours diagnosed during 2000-2003"; Environmental Research (2006) Volume 100; pages 232-241*). The group reported more substantial and significant data regarding the potential role of mobile phones in brain tumour development, as their study also assessed **long-term** users (those who at the time of their study had used mobile phones for **> 10 years**). Elevated risks (odds) of **2- to 4-fold** for brain tumour development in cell phone users were reported in this study. As the authors state: "Our main finding was a significantly increased risk for high-grade astrocytoma [an aggressive type of brain cancer] for all three studied phone types [namely, analogue, digital, and cordless]. The Odds Ratio [OR; likelihood of seeing the effect, in this study, effect = diagnosis of a brain tumour] increased both with the increasing number of hours of use and tumour latency period [suggesting a dose-dependent effect; i.e., the more the cumulative exposure to cell phone electromagnetic radiation, the more likely one would observe the development of a brain tumour]. The highest risk was found for a > 10-year latency period [i.e., time from first cell phone use to the time of diagnosis of a brain tumour]."
- In 2005, an international multicentre study partly sponsored by the cell phone industry was reported in the British Journal of Cancer. **678 "cases"** with **acoustic neuroma** (also known as "vestibular Schwannoma"; a brain tumour originating from the cranial nerve for balance and hearing) and **3553 matched "controls"** were surveyed in four Nordic countries and the UK. Although the study appeared

to show no association between cell phones and the development of acoustic neuroma, the authors of the study reported a **worrisome finding**: "Risk of a tumour on the **same side of the head** as reported phone use was raised for use for **10 years or longer** (almost **2-fold increased risk**)". They concluded "The study suggests there is no substantial risk of acoustic neuroma in the **first decade** after starting mobile phone use. However, an increase in risk after longer term use or after a longer lag period could not be ruled out." (*M.J. Schoemaker, et al., "Mobile phone use and risk of acoustic neuroma: results of the Interphone case-control study in five North European countries"; British Journal of Cancer (2005) Volume 93; pages 842-848*). Although the authors of this study played down their findings in their longer-term phone users, as stated by S. Milham in a Letter to the Editor about this study: "Given the long latencies of solid tumours in humans, I think that the pattern of these results suggests that we may be **at the beginning of an epidemic of cell phone induced tumours**, rather than the authors' claim of "...no substantial risk."" (*S. Milham, Letter to the Editor; British Journal of Cancer (2006) Volume 94; page 1351*).

- The above study by Shoemaker and colleagues substantiated the findings of a study published in the preceding year by Lonn and colleagues from Sweden (the first country to have a mass deployed mobile phone system). Lonn's group (*S. Lonn, et al., "Mobile phone use and the risk of acoustic neuroma"; Epidemiology (2004) Volume 15; pages 653-659*) reported interviewing **148 "cases"** (persons with acoustic neuromas) and **604 "controls"** and found that "ten years after the start of mobile phone use the estimates of relative risk [i.e., increased risk of developing an acoustic neuroma with regard to the duration of cell phone use] increased to 1.9 [i.e., **almost two-fold** increased risk]; when restricting to tumours on the **same side of the head** as the phone was normally used, the relative risk was 3.9 [i.e., **almost four-fold**]". The study by Lonn's group was also financially supported in part by the Cell Phone Industry (**INTERPHONE Study**; *E. Cardis,*

et al., "International case-control study of adult brain, head and neck tumours: Results of the feasibility study"; Radiation Protection Dosimetry (1999) Volume 83; pages 179-183).

- In 2006, a German group, also part of the **INTERPHONE Study**, published its findings regarding the incidence of brain tumours [(malignant) glioma and benign) meningioma] among **747 "cases"** and **1494 "controls"**, matched as usual for age, gender and region of residence. The findings of this study were generally negative, except "among persons who had **used cellular phones for 10 or more years**, increased risk was found for **glioma** (greater than **2-fold**) but not for meningioma" (*J. Schuz, et al., "Cellular phones, cordless phones, and the risks of glioma and meningioma (INTERPHONE Study Group, Germany)"; American Journal of Epidemiology (2006) Volume 163; pages 512-520*). While the authors concluded: "The results of this study do not indicate an overall increased risk of glioma or meningioma among regular cellular phone users...These findings are consistent with the majority of previous studies on this topic", **statements such as these are misleading** (see "Critique" section below). As pointed out by Morgan (*L.L. Morgan, Letter to the Editor, American Journal of Epidemiology (2006); Volume 164; pages 294-295*) in response to the comments of Schuz and colleagues: "The findings recently published by Schuz et al., similar to all of the Interphone Study results published to date, have **several serious problems**. For one thing, in their core findings, the authors report no risk of glioma or meningioma from "regular" use of cellular telephones ("regular" use being defined [by INTERPHONE researchers] as at least one incoming or outgoing call per week for 6 months or more [aside: this definition is **unacceptably minimalistic** and can result in **severe underestimation** of exposure risk], yet there is a **more than a doubling of glioma risk after more than 10 years of cell-phone use**...In addition, among women, they found close to a doubling of the risk of high-grade glioma from "regular" cell-phone use...Given the specific

problems of the study [elaborated in detail later in his Letter to the Editor] - all of which would produce underestimation of brain tumour risk - **these findings are ominous**".

- A more recent report from the INTERPHONE group by Lahkola and colleagues (*A. Lahkola, et al., "Mobile phone use and risk of glioma in 5 North European countries"; International Journal of Cancer (2007) Volume 120; pages 1769-1775*) details findings from interviews of **1521 "cases" of glioma** and **3301 "controls"**. Their positive findings came from considering the side of the tumour relative to the preferred side for cell phone use and the length of cell phone usage. Although they downplay this finding, the authors state: "One subset of analyses did, however, indicate a possible association with mobile phone use: reported **ipsilateral [same-side] use 10 or more years ago** was associated with significantly increased risk of glioma [malignant brain tumour] and there was also an increasing trend with years since first use on the ipsilateral side". They add: "Our study covers a **large number of cases and controls** compared with previously published reports...Additionally, the countries included in these analyses are pioneers in mobile phone use and therefore the number of mobile phone users with more than 10 years of exposure (88 cases) is larger than in previous analyses, which allows more reliable estimation of the risk related to such long-term mobile phone use."

(ii) "NEGATIVE" CLINICAL STUDIES - i.e., those that show **no statistically significant association** between cell phone usage and brain tumour development:

- A **massive study from Denmark** (*J. Schuz, et al., "Cellular telephone use and cancer risk: update of a nationwide Danish cohort"; Journal of the National Cancer Institute (2006); Volume 98: 1707-1713*) is widely quoted as "**proof there is no link** between mobile phone use and brain tumours." After all, this part of Europe was one of the first to pioneer the mass deployment of mobile phones

after Sweden and the authors state "...Danish cellular telephone users...were followed for **up to 21 years**". They later clarify that the **average cell phone usage time was 8.5 years**. While the authors received the records of a massive **723,421 cellular telephone subscriptions** in Demark during the period 1982 - 1995, **they excluded from this number 200,507 CORPORATE USERS** "because the individual users could not be identified". Therefore, not only were nearly **30% of potential participants excluded**, these 200,507 corporate users were **probably some of the most heavy** users of mobile phones ("free" business-related incoming and outgoing calls; tax deductible accounts) and therefore their exclusion represented the exclusion of a potentially invaluable source of information for this study. Further exclusions lead to data from 420,095 users being used for their study. Among over 56,000 longer term subscribers using their phones for 10 years or more (and not including data from potentially "heavy corporate users" who were all excluded from participation in this study), they recorded 28 brain tumours. Since the average brain tumour incidence rate is somewhere around 15 per 100,000 per year, a group of 56,000 people should generate 8 to 9 new brain tumours every year, i.e., 80 to 90 brain tumours after 10 years. Since the **authors only observed 28 brain tumours in their in this group** (**less than one-third of the expected number**), their findings suggest that long term use of cell phones protects (!!!) against the development of brain tumours in Denmark—this aberration has been thought to be due to fatal methodological problems with this large study, particularly the exclusion of most of the likely heavy users. However, the authors themselves point out: "Bias due to nonparticipation is NOT, however, a plausible explanation for the reduced brain tumour risk that we observed among long-term subscribers in this nationwide cohort study because the entire Danish population was included in the study." [An exclusion rate of almost 40% is not specifically elaborated, although the authors do elaborate upon the **strong bias introduced via the exclusion of all**

"corporate" users ("some of the most active users") and the fact that "**the majority of our reference population consists of recent cellular telephone users**,..."]. Further, the authors quote positive studies which looked at the side of the tumour and the side of preferred cell phone usage, but **they themselves carried out no such analysis**.

- *H. Collatz-Christensen, et al., "Cellular telephones and risk for brain tumours"; Neurology (2005) Volume 64; pages 1189-1195*. The authors surveyed **252 "cases"** with glioma and another **175 with meningioma** diagnosed in Denmark between 2000 and 2002; A further **822 matched "controls"** were surveyed. They found **no association** between the use of cell phones and risk for glioma and astrocytoma. However, as the authors themselves state: "In our study, **few persons reported regular cellular telephone use for 10 years or more**...Owing to the small numbers and the low statistical power of analyses on a national level,...more meaningful results will be obtained at the international level of the Interphone study" [see above for INTERPHONE study results].
- *J. Schuz, et al., "Radiofrequency electromagnetic fields emitted from base stations of DECT cordless phones and the risk of glioma and meningioma (Interphone Study Group, Germany)"; Radiation Research (2006) Volume 166; pages 116-119*. The authors surveyed **747 brain tumour "cases"** (years 2000-2003) and **1494 matched "controls"** in Germany. The exposure measure of their analysis was the location of a base station of a DECT (Digital enhanced cordless telecommunications) cordless phone close to the bed, which was used as a proxy for continuous low-level exposure to radiofrequency electromagnetic fields during the night. They found no association between DECT radiofrequency exposure and the risk of brain tumours, however, their study included a total of only 6 "cases" with exposures in excess of 5 years (!) and they report none with exposures of 10 years or more. Authors of this study by Schuz were also coauthors of Collatz-Christensen's study (see immediately above).

- *S. Hepworth, et al., "Mobile phone use and risk of glioma in adults: case-control study"; British Medical Journal (2006) Volume 332; pages 883-887.* The authors surveyed **966 brain tumour "cases"** (years 2000-2004) and **1494 matched "controls"** in the United Kingdom. They found "no relation for risk of glioma [the main malignant brain tumour] and time since first use, lifetime years of use, and cumulative number of calls and hours of use". However**, only 5% of cases had used a mobile phone for 10 years or more** (the average duration of use of a mobile phone in this study was 3 to 4 years). As pointed out by Michael Kundi, Head of the Institute of Environmental Health, Center for Public Health, Medical University of Vienna, "**Is there really any occupational or environmental factor capable of inducing glioma in a period of 3 to 4 years?...not even after high doses of therapeutic x rays have such short latencies been observed**." (*M. Kundi, Letter to the Editor; British Medical Journal (2006) Volume 332; pages 1035-1036*). Further, Lloyd Morgan, a retired electronic engineer in the USA, points out regarding the Hepworth study: "Editor, in years past Hepworth et al.'s study **would never have been published because low participation rate** would have been cause for rejection. With [only] 51% of cases and 45% of the controls participating there is little reason to believe any of the reported results....[and] regular cell phone use is defined [by Hepworth, et al.] as cellphone use for at least once a week for six months or more. **Regular cellphone use is set to such a minimal standard that few could imagine finding a risk**." (*L.L. Morgan, Letter to the Editor; British Medical Journal (2006) Volume 332; page 1035*). Yet, despite the shortcomings of their study, Hepworth and colleagues found "a **significant excess risk** for reported phone use **ipsilateral** to [on the same side as] the tumour", however they dismissed this finding as being due to **"recall bias"** among their tumour patients (i.e., patients being unable to accurately recall which side of the head they preferred to use their mobile phones, and perhaps

subconsciously assigning their "preferred side" for usage to the same side as their eventually diagnosed brain tumour).

- *L. Hardell, et al., "Use of cellular and cordless telephones and risk of testicular cancer"; International Journal of Andrology (2007) Volume 30; pages 115-122*. *Regarding cell phones and testicular cancer ("cases" diagnosed between 1993 and 1997 in provinces of Sweden*), these authors found that there was **no dose-response effect** and the odds ratio did not increase with latency time. No association was found with place of keeping the mobile phone during standby, such as the trousers pocket. There were **barely a few patients in this study who had used mobile phones for 10 or more years** (and none in the digital phone group). Despite their negative findings with regard to testicular cancer, the authors quoted work regarding a **genotoxic effect on epididymal spermatozoa** (i.e., reduced sperm count, motility and/or quality) in mice exposed to 900 MHz microwaves. Such findings have been also been supported by laboratory (in vitro) studies involving human sperm exposed to 900 MHz cell phone radiation (after exposures of only 5 minutes!), and are reviewed by Erogul and colleagues (*O. Erogul, et al., "Effects of electromagnetic radiation from a cellular phone on human sperm motility: An in vitro study"; Archives of Medical Research (2006) Volume 37; pages 840-843*).
- Other "negative studies" are listed here for the reader's reference. Most of these suffer from **limited follow-up** [few or no long-term (10 years or more) users of cell phones] and/or lack of inclusion in their investigation any analysis of the **side of the head** preferred for cell phone usage and the side of the head in which the brain tumour eventually developed. In the context of what is now becoming apparent in numerous "positive studies" (see earlier), very significant limitations of the "negative" studies can be referred to as **lack of "latency" and "laterality" analyses**, respectively. **Notably, the lead authors of some negative or "no link" studies have recently published findings to the contrary, including S. Lonn**

and the authors of the two of the most substantial "no link" publications to date, namely, S. Schuz (from the massive Danish study) and A. Lahkola (from the "no link" meta-analysis quoted immediately below).

- *T. Takebayashi, et al., "Mobile phone use and acoustic neuroma risk in Japan"; Occupation and Environmental Medicine (2006) Volume 63; pages 802-807.*
- *A. Lahkola, et al., "Meta-analysis of mobile phone use and intracranial tumours"; Scandinavian Journal of Work and Environmental Health (2006) Volume 32; pages 169-170.*
- *J. Muskat, et al., "Mobile telephones and rates of brain cancer"; Neuroepidemiology (2006) Volume 27; pages 55-56.*
- *P.D. Inskip, et al., "Cellular telephone use and brain tumours"; New England Journal of Medicine (2001) Volume 344; pages 79-86.*
- *S. Lonn, et al., "Long-term mobile phone use and brain tumour risk"; American Journal of Epidemiology (2005) Volume 161; pages 526-535.*

B. Laboratory Studies:

It has often been stated that there is no plausible mechanism through which a mobile phone can cause or promote cancer. While many laboratory studies have suggested mechanisms through which this can occur, others have contested those findings. One key problem with the design of all laboratory studies, both for and against a molecular link between cell-phone electromagnetic radiation and brain tumour development, is that such studies fail (for understandable reasons) to be carried out in time frames consistent with brain tumour development, i.e., **> 10 years**. Another problem with experimental design is that it frequently doesn't take into account the **additive or cumulative** effects of multiple, long-term exposure sources (mobile phones, cordless phones and their base stations, WiFi systems, TV antennae, radio antennae, and so forth).

(i) "POSITIVE" LABORATORY STUDIES - i.e., those studies that **show an association** between electromagnetic radiation and cellular changes that can lead to tumour development.

- Chou and colleagues (*C.K. Chou, et al., "Long-term, low-level microwave irradiation of rats"; Bioelectromagnetics (1992) Volume 13; pages 469-496*) exposed rats to 2450 MHz RF energy for just over **2 years** at a whole body specific absorption rate (SAR) of 0.15 - 0.4 W per kg (current standard for SAR by the FCC is 1.6 W/kg for the head; or 0.080 W/kg averaged over the body as defined by the International Commission on Non-Ionizing Radiation Protection (ICNIRP) guidelines). They found an **excess of malignant tumours** in exposed animals, but no difference in life span, no increases in any particular type of tumour, and no malignant brain tumours at all. The study exposed animals to only 2 years of radiation (instead of, say, 10 years) and at possibly lower "doses" than currently permitted for cell phones alone (although SAR for the rat head was not specified). The fact that there was an increase in the number of malignant tumours observed in exposed animals under these conditions certainly is of concern.
- Repacholi and colleagues (*M.H. Repacholi, et al., "Lymphomas in Eu-Pim1 transgenic mice exposed to pulsed 900 MHz electromagnetic fields"; Radiation Research (1997) Volume 147; pages 631-640*) exposed **"transgenic" mice** (that were genetically engineered to be more prone to developing lymphomas) to 900 MHz radiofrequency energy for 18 months at an specific absorption rate (SAR) of 0.008 - 4.2 W per kg (the variation in SAR due to variations in mice size, orientation, and number remaining in cages). They found that the incidence of **lymphoma in the exposed mice was significantly higher** than in unexposed control mice, suggesting a **tumour-promoting** effect of radiofrequency electromagnetic radiation.
- Lai & Singh reported **increased levels of DNA damage** in rat brain cells after exposure to 2450 MHz pulsed or continuous-wave radiofrequency energy (*H. Lai*

& N.P. Singh, "Acute low-intensity microwave exposure increases DNA single-strand breaks in rat brain cells"; Bioelectomagnetics (1995) Volume 16: pages 207-210) and a biological means of preventing this DNA damage from occurring (*H. Lai & N.P. Singh, "Melatonin and a spin-trap compound block radiofrequency electromagnetic radiation-induced DNA strand breaks in rat brain cells"; Bioelectomagnetics (1997) Volume 18: pages 446-454*).

- Takashima and colleagues exposed Chinese hamster ovary (CHO-K1) cells to either **continuous or intermittent radiofrequency electromagnetic fields** over relatively brief time periods (a few minutes!!) but at relatively high specific absorption rates (SARs) to determine the effects of such radiation on cell growth, survival, and cell cycle distribution. They found that at an SAR of 200 W per kg (well above the recommended 1.6 W per kg for the human head) of a continuous radiofrequency field, **cell growth rate and cell survival decreased**, and the temperature of the incubation medium rose significantly. This effect was not seen for exposures at similar SARs to intermittent radiofrequency fields. The authors concluded that the **thermal** (temperature-elevating) effect of electromagnetic fields **caused impairment** of cell growth and survival but not cell cycle distribution (*Y. Takashima, et al., "Effects of continuous and intermittent exposure to RF fields with a wide range of SARs on cell growth, survival, and cell cycle distribution"; Bioelectromagnetics (2006) Volume 27; pages 392-400*). However, these exposure conditions were certainly not reflective of those experienced by cell phone users in every day life; i.e., **non-physiological conditions** were used here.
- In 2005, Diem and colleagues reported the findings of a **more "physiological" (i.e., realistic) study** than that carried out by Takashima et al. (see above). Diem's group used cell cultures of human fibroblasts and rat granulosa cells exposed to similar intermittent and continuous radiofrequency electromagnetic fields associated with mobile phones (1800 MHz; SAR 1.2 or 2 Watts per kg; exposure

times in the order of hours). They found that this level of exposure induced DNA single- and double-strand breaks, with effects observed after 16 hours of exposure in both cell types and after different mobile-phone modulations. The intermittent exposure showed a stronger effect, and suggested that DNA damage was based on **non-thermal effects** (*E. Diem, et al., Non-thermal DNA breakage by mobile-phone radiation (1800 MHz) in human fibroblasts and in transformed GFSH-R17 rat granulosa cells in vitro"; Mutation Research (2005) Volume 583; pages 178-183*).

- Using **transcranial magnetic stimulation technology** in 15 volunteers, Ferreri and coworkers tested the excitability of each brain hemisphere after "real" or "sham" exposure to electromagnetic fields generated by a GSM mobile phone. An optimal cross-over, **double-blind study** model was used; their findings were published in the leading neurology journal (*F. Ferreri, et al., "Mobile phone emissions and human brain excitability"; Annals of Neurology (2006) Volume 60; pages 188-196*). They found that **brain (intracortical) excitability curve became significantly modified towards hyperexcitability** (implying increased cortical cellular activity) during **"real" exposure** on the side of the brain immediately adjacent to the exposure source, in this case a GSM mobile phone operating for 45 minutes. The **ear drum (tympanic) temperature showed no significant variation** in this study. The authors concluded that GSM electromagnetic fields increased brain excitability [consistent with their ability to interfere with aircraft and intensive care unit electrical equipment at remote distances] and postulated that this may over repetitive and long-term time intervals of exposure increase **cellular ("oxidative") stress**; an event that may lead to cellular injury pending further laboratory investigation.
- Panagopoulos and colleagues exposed fruit flies (*Drosophila melanogaster*) to Global System for Mobile Telecommunication (GSM; 900 MHz) and Digital Cellular System (DCS; 1800 MHz) radiation from a common digital mobile

phone for a few minutes a day during the first 6 days of their adult lives. They found **increased DNA fragmentation** and (nonphysiological, non-programmed) **cell death** induced by both types of mobile telephony radiation (*D.J. Panagopoulos, et al., "Cell death induced by GSM 900-MHz and DCS 1800-MHz mobile telephony radiation"; Mutation Research (2007) Volume 626; pages 69-78*). Weisbrot and colleagues showed that even discontinuous (akin to intermittent or pulsed) radiofrequency signals from mobile phones (900 & 1900 MHz; SAR 1.4 W/kg) caused **significant gene and protein changes**, and also resulted in increased numbers of offspring when fruit flies were irradiated during the 10-day developmental period from egg laying through pupation. Interestingly, they found **rapid induction of heat shock protein 70** (hsp70; a protein involved in protecting certain cellular molecules from injury) within minutes by non-thermal radiofrequency stress (*D. Weisbrot, et al., "Effects of mobile phone radiation on reproduction and development in Drosophila melanogaster; Journal of Cellular Biochemistry (2003) Volume 89; pages 48-55*).

- Consistent with the ability of cell phone radiation to cause cellular changes, Remondini and colleagues exposed a variety of human cell lines to 900 and 1800 MHz electromagnetic radiation ("exposed"; 1 to 44 hours; SAR 1 - 2.5 W/kg, **continuous or intermittent/pulsed exposures**) versus no radiation ("sham"), and in certain of these cell lines found dozens of **up- and down-regulated genes** (i.e., genes whose "expression" was increased or decreased), mainly subserving the function of cell **metabolism** (although **heat shock protein 90**, a relative of heat shock protein 70, was found to be downregulated in endothelial cells). Interestingly, up- or- down-regulation of certain genes varied according to the type of exposure, i.e., continuous versus intermittent (*D. Remondini, et al., "Gene expression changes in human cells after exposure to mobile phone microwaves"; Proteomics (2006) Volume 6; pages 4745-4754*). Further, **human sperm motility** has been shown to be **significantly impaired** following exposure to 5 minutes of

900 MHz cell phone radiation at standard power output and power density (*O. Erogul, et al., "Effects of electromagnetic radiation from a cellular phone on human sperm motility: An in vitro study"; Archives of Medical Research (2006) Volume 37; pages 840-843*).

- Mashevich and colleagues exposed human white blood cells to 830 MHz electromagnetic fields, exposure occurring for 72 hours with specific absorption rates (SARs) of 1.6 - 8.8 W/kg (per the US FCC, the current maximum SAR for the head is 1.6 W/kg). They found a **dose-response of cellular/genetic abnormalities**, namely a linear increase in **chromosome 17 aneuploidy** (a major "somatic" mutation leading to "**genomic instability**" and cancer), the degree of aneuploidy increasing with SAR. They concluded that, per their experimental model, "**the genotoxic effect of the electromagnetic radiation is elicited via a non-thermal pathway**" (*M. Mashevich, et al., "Exposure of human peripheral blood lymphocytes to electromagnetic fields associated with cellular phones leads to chromosomal instability"; Bioelectromagnetics (2003) Volume 23; pages 82-90*).

(ii) "NEGATIVE" LABORATORY STUDIES - i.e., those studies that **show NO association** between electromagnetic radiation and cellular changes that can lead to tumour development.

- The effects of 860 MHz radiofrequency radiation (**continuous and pulsed** from local cage antennae with 1 W average power output; SAR 1 W/kg averaged over the brain) for **6 hours a day, 5 days a week from 2 months to 24 months** on tumour development was studied in hundreds of rats, as reported by Zook and Simmens. They found **no statistically significant evidence** that this type and extent of radiation exposure caused or promoted any type of tumour in rat brain or spinal tissues. Although the study was very comprehensively constructed, it

limited follow up to **2 years maximum** in rats and assumed that this follow-up was an equivalent period to at least 10 years of brain tumour induction times in humans. The study was **funded by Motorola Corporation**, leading to ethical concerns regarding conflict of interest. Finally, the **natural occurrence of rat brain tumours is 1 - 2%,** but this study found that even their **"unexposed" ("control") rats** showed brain **tumour rates of 7 - 8%,** i.e., much higher than expected and for unknown reasons (? chance; or perhaps even "unexposed" rats were **inadvertently close to antennae** used on other "exposed" rats in this study; B.*C. Zook & S.J. Simmens, "The effects of 860 MHz radiofrequency radiation on the induction or promotion of brain tumours and other neoplasms in rats"; Radiation Research (2001) Volume 155; pages 572-583*).

- Sakuma and colleagues (*S. Sakuma, et al., "DNA strand breaks are not induced in human cells exposed to 2.1425 GHz band CW and W-CDMA modulated radiofrequency fields allocated to mobile radio base stations"; Bioelectromagnetics (2006) Volume 27; pages 51-57*) examined the effects of **cordless phone base station radiation** (2.1425 GHz or 2143 MHz; 2 hr and 24 hr exposure times; continuous wave **SAR of up to 80 mW/kg** [averaged over the body; corresponding to the limit of the whole body SAR for general public exposure as defined by the International Commission on Non-Ionizing Radiation Protection (**ICNIRP**) guidelines]) on **highly abnormal human glioblastoma** cells and normal human lung fibroblasts. They found that low level exposures do not act as a genotoxicant up to a SAR of 800 mW/kg (or 0.8 W/kg). Reasons for the use of the most highly malignant (molecularly unstable) brain tumour cell line in this experimental paradigm remains unclear. **Why a variety of radiation levels were not tested** (i.e., more robust testing for dose-dependence) also remains unclear. Similar "negative" results (i.e., no DNA damaging effects) were reported by Malyapa and colleagues in these cell types exposed to radiofrequency radiation for 24 hrs (800 - 900 MHz; 0.6 W/kg; *R.S. Malyapa, et al., "Measurement of DNA*

damage after exposure to electromagnetic radiation in the cellular phone communication frequency band (835.62 and 847.74 MHz); Radiation Research (1997) Volume 148; pages 618-617). **No clear relationship of this exposure level (in cell culture) to the FCC or ICNIRP recommended levels (whole body and head) was detailed.**

- Lee and colleagues exposed **abnormal human T-lymphocytes** (**Jurkat cells** derived from a malignant leukaemia in a child 40 years ago) and normal rat brain astrocytes to 1763 M Hz radiation (SAR 2 W/kg or 20 W/kg) for 30 minutes or 1 hour. They found no effect on heat shock protein (HSP) expression or the activation of mitogen-activated protein kinases (MAPK) -- parts of cell signaling associated with cell stress response/cell injury (*J.S. Lee, et al., "Radiofrequency radiation does not induce stress response in human T-lymphocytes and rat primary astrocytes"; Bioelectromagnetics (2006) Volume 27; pages 578-588*).
- A well designed study by Thorlin and colleagues found no effect of 900 MHz microwave radiation (SAR 3-27 W/kg; exposures up to 24 hrs) on the leaching molecular markers for cell damage (interleukin 6, IL-6; tumour necrosis factor alpha, TNF-a; glial fibrillary acid protein; GFAP) into the culture medium. Nor did they find evidence for microscopic cell damage. They concluded that: "this study does not provide evidence for any effect of the microwave radiation used on damage-related factors in glial cells in culture" (*T. Thorlin, et al., "Exposure of cultured astroglial and microglial brain cells to 900 MHz microwave radiation"; Radiation Research (2006) Volume 166; pages 409-421*). Again, **it is unclear how a short-term period of radiation of cells correlates to life-long radiation exposure to the body, or intermittently high near-field exposures to the head.**
- A summary of positive and negative clinical and laboratory studies prior to 2005 can also be found in the article by Moulder and colleagues (*J.E. Moulder, et al., "Mobile phones, mobile phone base stations and cancer: a review"; International Journal of Radiation Biology (2005) Volume 81; pages 189-203*).

C. Critiques of the clinical studies:

(i) <u>Criticising a "negative" clinical study:</u> Those who have criticised "negative clinical studies" that demonstrated no statistically significant link between mobile phone usage and brain tumours frequently report **one or more of the following reasons**. Namely, the negative clinical study may have:

- **Failed to include the heaviest users**, e.g., corporate users or people using mobile phones for hours in a day over extended periods of time. That is, such studies were suboptimal due to "**selection bias**";
- Involved a **relatively short follow-up time**, i.e., < 10 years of mobile phone usage. That is, a length of time too short to meaningfully associate with brain tumour development and detection;
- Been **partly funded by the Telecommunications Industry** itself (representing a potentially serious "**conflict of interest**"). In such cases, the contract may have also stipulated that the industry has the right to be informed about the results prior to the publication of the study, with obvious implications;
- Not focused on the types of brain tumours related to electromagnetic radiation such as **astrocytoma** (the most common type of "glioma"), meningioma, and **acoustic neuroma** (aka vestibular Schwannoma);
- Not considered the **favoured side of the head** that the mobile phone was used, and the side of the head that the brain tumour developed;
- Failed to have used an **appropriate "control"** group such as persons who rarely use cell phones and who rarely use cordless phones;
- Had **low participation rates**.

(ii) Criticising a positive clinical study: Those who have criticised "positive clinical studies" that demonstrated a statistically significant link between mobile phone usage and brain tumours frequently report **one or more of the following reasons**. Namely, the positive clinical study may have:

- Relied on **self-reported duration and frequency** of mobile phone usage (deemed to subject to "**recall bias**" and therefore inaccurate compared with computerised logs of incoming AND outgoing calls for each user -- unfortunately such logs may not be maintained or made available by Telecommunication companies);
- Relied on **self-reported favored sided of head** for mobile phone usage (deemed to be subject to "**recall bias**"; i.e., if the user developed a brain tumour on one side of the head, they may, owing to their knowledge of which side of their head the tumour was found, inaccurately "recall" that they used the mobile phone more on that side of the head);
- Relatively **small numbers** of long-term users;

As an aside, some "negative" studies have been re-analysed, and found to in fact be "positive". That is, where certain studies originally reported "no association" between cell phone usage and brain tumours, reanalysis by astute individuals has shown in fact that their data indeed supports an association between cell phone usage and brain tumours. Further, **it is notable that the lead authors of two of the most influential "negative studies" in print –** namely, **the massive Denmark study** quoted earlier **(***J. Schuz, et al., "Cellular telephone use and cancer risk: update of a nationwide Danish cohort"; Journal of the National Cancer Institute (2006); Volume 98: 1707-1713*), and a **"negative" "meta-analysis" (***A. Lahkola, et al., "Meta-analysis of mobile phone use and intracranial tumours"; Scandinavian Journal of Work and Environmental Health (2006) Volume 32; pages 169-170*) - **have subsequently published studies with findings to the contrary (i.e., now with data supporting a link between mobile phones and brain tumours).**

8. CONCLUSIONS:

The Conclusions section represents a concise statement of the main findings of the study and its message.

Emerging concepts and concerns:

- **Electromagnetic radiation** such as that emitted by mobile and cordless phones can **heat the side of the head** or **pulse it non-thermally** and potentially thermoelectrically interact with its organic electrical content, the brain.
- **Bluetooth devices and unshielded headsets** can convert the user's head into an effective, potentially **self-harming antenna**.
- **Malignant brain tumours** may take **several years to develop**, and the **incidence** of malignant brain tumours is **increasing**.
- There is a growing and statistically significant body of evidence reporting that brain tumours such as **vestibular Schwannoma** (acoustic neuroma) and **astrocytoma** are associated with **"heavy" and "prolonged" mobile phone** use, particularly on the **same side** as the "preferred ear" for telephony.
- Certain **"heavy" mobile-phone** users may be more susceptible to developing malignant brain tumours compared with others reporting similar patterns of mobile phone usage, and this may be **genetically predetermined** if the pattern and source of exposure are the same.
- In order to adequately observe and potentially confirm this association, a solid scientific study must observe "heavy" mobile phone users for a **period of at least 10-15 years** and in this subgroup of "heavy" users examine the relationship between the side of any newly diagnosed acoustic neuroma or astrocytoma and the "preferred side" for mobile phone usage.
- While mobile and cellular phones are convenient and useful, and in some situations life-saving, the Telecommunications Industry and its regulators are

implored to make these technologies and their accessories decidedly safer and then available to consumers.

- We are currently experiencing a relatively unchecked and dangerous situation related to both **"consumption at all costs"** and **"production at all costs"**.
- Worldwide availability and use of **appropriately shielded** cell phones and hands-free devices including headsets, **increased use of landlines** and pagers instead of current mobile and cell phones, and restricted use of **cellular and cordless** phones among children and adults alike are likely to limit the effects of this physically "invisible" danger.
- The author fears that unless the Industry and Governments take immediate and decisive steps to openly **acknowledge and intervene** in this situation, even while waiting definitive confirmation by large and well-constructed multi-centre studies worldwide, **malignant brain tumour incidence** and its associated death rate will be observed globally to rise within a decade from now, by which time it may be far too late to meaningfully intervene, especially for those who are currently children and young adults.

9. PRECAUTIONARY RECOMMENDATIONS:

The Precautionary Recommendations lays out in point form the evidence-based personal health and safety guidelines recommended by the author regarding mobile phones.

For members of the General Public:

- Avoid directly exposing the "hearing system" and brain to electromagnetic radiation by **using a regular "landline"** in preference to a hand-held mobile or cordless phone;
- When requiring to use a mobile phone, **increase the physical distance** between the device and the side of the head by using its "speaker phone" mode (with at least 20 cm separation) or "in-vehicle hands-free" mode;
- Avoid converting the head into a **mobile antenna** by **minimising** the use of current **Bluetooth** devices and **unshielded wired-earphones** for mobile phones;
- **Minimise the time** spent using mobile and cellular phones for all adults;
- **Restrict the use** of mobile and cellular phones by children to emergency situations.

For members of the Telecommunications Industry:

- Expedite the **research, development and promotion** of safe and economical shielding devices for mobile and cellular phones and their Bluetooth and headset accessories - some of these are already available but currently poorly marketed;
- Further **refine the quality** of hands-free "speaker phone" mode.

For members of the Health and Scientific Communities:

- **Objectively reanalyse** all previous large-scale population studies that reported "no link between mobile phones and brain tumours", particularly from the perspectives of whether those "apparently negative or inconclusive studies"

examined: (i) the length of usage of mobile phones greater than 10 years; (ii) following a cohort of "heavy" mobile phone users for more than 10 years; (iii) the occurrence of acoustic neuroma (vestibular Schwannoma) and/or astrocytoma in the study population (the two types of potentially malignant brain tumours reportedly associated with prolonged ipsilateral mobile phone usage); and (iv) the concept of "lateralisation" - that is, the relationship between the side of the brain tumour and the "preferred side" for mobile phone usage particularly in "heavy" users who developed brain tumours;

- Carry our **further large-scale studies** taking all of the aforementioned perspectives into account. Such studies are recommended and encouraged by the author in order to definitively validate or refute the findings of this paper.

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