FREQUENCIES USED IN TELECOMMUNICATIONS

An Integrated Radiobiological Assessment

Yuri G. Grigoriev

Translated and adapted by ORSAA

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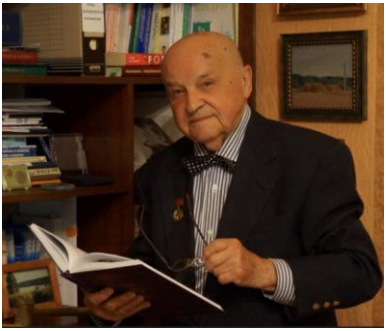

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*ORSAA is the Oceania Radiofrequency Scientific Advisory Association Inc (www.orsaa.org). ORSAA is a not-for-profit group of independent researchers investigating the biological and health effects of man-made electromagnetic fields and radiation. ORSAA has collated the world's largest online database of papers published this area (ODEB). Over two thirds of the published, peer reviewed papers show effects. ORSAA was asked by Yuri to help translate his book from Russian into English, and so the ORSAA translation team worked with Yuri on this task in the last six months prior to his passing. The team has taken the original work and adapted it for English readers, altering the structure of sections and adding explanations where necessary, but always staying true to the science and the meaning that Yuri was trying to convey. Yuri was extremely passionate about getting this message out to the world, a message that he had spent a lifetime researching. It is the hope of the ORSAA team that these pages live up to Yuri's wishes for his book.

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Foreword by ORSAA

(Oceania Radiofrequency Scientific Advisory Association)

This book brings a timely warning message to a world intent on further densification of background artificial electromagnetic fields (EMFs) to the point of saturating the planet. The current level of human-made EMF already sits at a quintillion (10^{18}) times the earth's natural background levels. These levels continue to rise in spite of very limited biological testing and the many warnings from independent scientists over the last five decades. Ubiquitous 5G is now to be added to the existing 3G and 4G systems, covering the earth and sky, and invading the ionosphere.

Artificial radiofrequency (RF) radiation has already been shown to be a potentially carcinogenic agent, damaging to DNA and creating many other biological and health effects.

ORSAA has assisted with the translation and revision of this book with a view to understanding the reasoning behind the Russian precautionary approach to the roll-out of wireless technology. Sadly, one of the authors, Professor Yuri Grigoriev, a giant in the science of Radiobiology, passed away in the midst of the translation and revision of the book. Over the past seven decades, Professor Grigoriev orchestrated many large-scale experiments and practical projects in ionizing and non-ionizing radiation science and protection. The output of this work has been used in health care, medical science, the military, and in space research. Grigoriev's breadth and depth of understanding of the interactions between biology and physics should not be ignored by governments, telecommunications engineers or social scientists charged with responsible decision-making in this matter. ORSAA has considered it both an honour and a duty to complete this project, in fulfillment of his urgent wishes.

Professor Grigoriev was privy to many decades of research regarding non-ionizing radiation in Russia and the Eastern bloc countries. The reader is herein given access and insight into results from these studies. It becomes clearer with each turn of the page that these research results corroborate and amplify the many warning messages of biological harm revealed in the enormous database of scientific studies already available to the

West, from military studies beginning in the 70s to sound biophysics of the 80s, and decades of independent research from universities and other institutions.

In these pages the authors describe the biophysics of exposures to EMF using clear explanations and solid logic. The industry premise that 5G millimeter waves (which are characterized by complex modulations) will only be absorbed in the skin and thereby only increase surface heating, is revealed to be shallow and false. As the book explains, the skin is a major critical organ of the body when it comes to millimeter wave exposures. It is rich in nerves, and innervated by the peripheral nervous system, including the autonomic nervous system. The skin is also the body's first line of defence against chemical or mechanical assault. Concerns are also raised for the cornea and sclera of the eyes, for which there is no current relevant experimental data.

The many decades of work in Russia and Eastern bloc countries on bio-resonance have provided a qualitative shift in understanding the interactions between MMW signals and human systems. Use of bio-resonance as a framework has allowed for the integration of seemingly puzzling results from various corners such as the discovery of amplitude and frequency "windows" and non-linear dose-response characteristics. Both experimental and theoretical work regarding bio-resonance is reviewed within this text. Included in this work is evidence for mechanisms in the body and the immune system that specifically recognise various forms of MMW radiation. These systems are changed as a result of their interactions with MMWs, and moreover, they accumulate bioeffects.

These bio-resonance findings provide principles of immense significance for better understanding of the immune system and human sensitivity to EMFs. Such principles are now being developed in Western medicine and safety science; e.g., Geesink and Meijer (2020) have used bio-resonance and quantum coherence in order to provide a framework for explaining why experimentally observed effects are dependent on frequency bands and power density. A better understanding of bio-resonance could assist microwave technology to move out from the currently unhealthy situation and into safer, more bio-compatible systems. Exploration of bio-resonance effects may also open up new methods for healing, thereby creating a qualitative shift in medical science.

The authors have taken an approach to radiation protection that prioritises the health and safety of the population, including more vulnerable exposure groups such as children.

The Russian scientists point out that our current exposures to RF, although deemed by western authorities to be "low-power", are ongoing, 24 hours per day, seven days a week, and are biologically active. Therefore, these anthropogenic electromagnetic energy exposures cannot be considered to be risk free, particularly for more vulnerable population groups. Their approach is in stark contrast to the approach taken by ICNIRP, FCC (US), and ARPANSA (Australia). Unfortunately for humankind, these organizations, which are responsible for our protection, require conclusive proof of harm before they will acknowledge the risks. The International Commission on Non-Ionizing Radiation Protection (ICNIRP) is a self-appointed non-governmental agency, which stands accused of having major conflicts of interest, and where the membership selection process is shrouded in secrecy. ICNIRP continues to ignore long-term non-thermal bioeffects in setting their guidelines, and it is these guidelines that are used in the West to set global standards which have allowed industry to proceed unencumbered by any real safety regulations.

We gratefully acknowledge the academic and organizational work of ORSAA's retired radiation health physicist, Victor Leach, as well as the team of editors and other professionals who have worked tirelessly to bring this revised and translated version of the original Russian book to fruition. We recommend this text as an enlightening read for those concerned with the health implications of man-made microwave radiation, including 5G signals.

ORSAA, 2021

Original Russian Foreword

In Russia, as in many countries, there have been active discussions over the past few years about a promising proposal for optimizing cellular communications. This has culminated in the worldwide implementation of the new 5G technological standard which will guarantee fast transmission of vast amounts of data. For this purpose, millimeter wave (MMW) electromagnetic radiation will be used.

The techno-economic advantages are far-reaching and widely reported by the media around the world. However, the degree of risk this type of electromagnetic radiation poses to public health and the environment remains unclear.

Scientists and medical professionals have appealed to the United Nations and the European Union regarding the necessity for preliminary medical and biological research before implementing the 5G standard. Unfortunately, these appeals have not been acted upon. A number of countries who question the need for the 5G implementation are pondering the health consequences of the densification of EMF pollution.

This book by Yuri. G. Grigoriev, et.al, *The 5G Health Risk– An Integrated Radiobiological Assessment,* examines the potential health implications of the implementation of the 5G standard within the cellular communication system. In contrast to the already existing 2G, 3G and 4G wireless technologies, which use electromagnetic fields in the *radio* frequency range, the 5G standard additionally utilizes *millimeter waves* to incorporate the network connections of the Internet of Things (IoT).

In order to ensure the stable delivery of MMWs to cover the entire territory of our planet, Earth satellites are used. The launch of 4,425 satellites has been planned to implement the provision of universal Internet access. There are already 800 satellites in space under this program.

As a result, the entire population of the earth will be trapped for life in an electromagnetic grid of millimeter waves and no one will be able to avoid their impact.

It should be noted that there are currently several thousand satellites in orbit. This fact is of great concern to astronomers (in the context of light pollution) and also for space agencies regarding the safe service of personnel on space flights in Russia. Space junk (debris) is a major problem as collisions create an ever-increasing number of high velocity projectiles that could threaten global communications. Debris larger than the size of a tennis ball is currently being tracked, however, NASA has reported over 500,000 untracked objects.

MMWs, unlike the current microwave frequencies used for 4G communication, are easily blocked by objects. In practice, to cover a certain area with a millimeter cell, you will need to increase the number of base stations (BS). For example, if the cell radius is only 20 meters, you will need about 800 base stations per square kilometer, located three to five meters from the consumer. This is in sharp contrast, for example, with 3G and 4G requirements, which use large cells and have ranges from 2 to 15 km or more.

Since millimeter waves are absorbed in body tissue at a depth of up to 2 mm, only the skin and sclera (white section) of the eye will be affected by them. The authors therefore correctly believe that when assessing the risk of MMW exposures, it is necessary to take into account the presence of two new critical organs, the skin and the eyes. The skin is a very complex biostructure. It is the largest organ in the body and has a large number of receptors. Skin acts as a "bio-relay" between the external environment and the functional state of the body.

Naturally, the introduction of 5G technology in the communications system raises new questions. Firstly, there are the technical requirements for the successful use of this type of communication: a significantly larger number of micro-antenna base stations (i.e., antennas) per unit area with satellite support is needed. Secondly, there is the lack of a consistent methodology for health and safety. Thirdly, thus far, there are only *assumptions* about the possible biological effects of a lifetime of exposure to MMWs on human populations and ecosystems. There is no long-term data on possible health effects from constant exposure to MMWs on the skin and sclera of the eyes. Targeted research or pre-market testing has not been performed in Russia or other countries prior to implementation of this new technology.

There are different perspectives on the assessment of the potential hazards of this new technology. The International Commission on Non-ionizing Radiation Protection (ICNIRP) and the US Federal Communications Commission (FCC) assess risk by considering only the additional absorbed dose of electromagnetic thermal energy, according to the pre-existing radiofrequency (RF) standards. This additional dose is considered insignificant (in terms of energy transfer) and therefore the existing FCC and ICNIRP standards, approved back in 1996, are not being materially revised to include other non-thermal emerging potential health aspects. International standards, despite the criticism of the scientific community and the European Union, have remained unchanged for more than 20 years.

The authors of this book assert that the ICNIRP approach is in error since the radiation loads on new critical organs (the skin and the eyes) are not taken into account. The authors contend that the significance of radiobiological criteria and the degree of risk from the emergence of the new critical organs *must* be considered; in particular, the load on existing critical organs and systems, with a view to lifetime exposure of the population to electromagnetic fields (EMFs). From this point of view, this book presents an assessment of the total radiobiological danger of planetary electromagnetic radiation exposure to the population.

The book offers the reader new ways to reduce the electromagnetic load, taking into consideration 5G exposures on the human population. It is necessary to explain to the public that radiofrequency electromagnetic radiation can be harmful and that their protection is regulated by certain radiation protection standards. Exposure to EMFs that exceeds these standards may negatively affect the health of the mobile (wireless) communications user. In this regard, the public should strictly follow the existing health and safety recommendations. Most people, however, perceive their wireless devices simply as a convenient part of everyday life, for entertainment, or as a toy for children. They use wireless communications without restriction and do not consider limiting their conversation time. The general public needs to be made aware that they are violating radiation protection recommendations and putting themselves and their children at risk. This danger must be clearly and persistently explained through public health messaging and in the media. It is necessary to introduce the concept of "exposure risk awareness". Strong consumer protection advice is required but the telecommunications industry, as well as governments, are reluctant to give this advice as it will acknowledge that these devices are not risk-free and could also adversely affect their profits.

To our knowledge this is the first book on 5G that outlines the potential dangers of 5G technology, both in Russia and overseas. The publication of this book is timely.

Author's Preface

This book discusses the implementation of the 5G standard in the cellular communication system. This implementation involves the use of millimeter waves (MMW) for a broadband wireless connection between devices such as mobile phones and other 5G-enabled devices and objects. Uses will include telephony and connection to the internet, as well as the simultaneous distribution of the IoT (Internet of Things). The IoT is the wireless connectivity between millions of devices in homes and offices, as well as those used, for example, in transport and production.

As MMWs are easily absorbed, the main areas of concern for human exposures have been effects on the skin and eyes.

This book presents a new radiobiological approach to assess health hazards of the 5G standard. The significance of radiobiological criteria and the degree of risk are weighed to include a consideration of the implications of the appearance of new critical organs, and the load on existing critical organs and systems during a lifetime exposure to electromagnetic fields (EMF) in the population. This integrative perspective is used by the authors to assess the total radiobiological danger of planet-wide electromagnetic radiation exposure to the population.

Strategies to reduce the electromagnetic load on the population are suggested.

List of Abbreviations

Abbreviation	Description
5G	The "fifth generation" telecommunications technology standard for broadband cellular networks
AAEM	American Academy of Environmental Medicine
ACNEM	Australasian College of Nutritional and Environmental Medicine
ANSI	American National Standards Institute
ARPANSA	Australian Radiation Protection and Nuclear Safety Agency
BAP	Biologically active point
BBB	Blood brain barrier
BEMS	Bioelectromagnetics Society
BS	Base station
BSEM	British Society for Ecological Medicine
CDMA	Code Division Multiple Access
COMAR	IEEE - Committee on Man and Radiation
DNA	Deoxyribonucleic Acid
DTH	Delayed-type hypersensitivity (type IV)
EEG	Electroencephalogram
ELF	Extra low frequency
ELF-EMF	Extra low frequency electromagnetic fields
ELISA	Enzyme-linked immunosorbent assay
EMF	Electromagnetic field
EMR	Electromagnetic radiation
EU	European Union
EUROPAEM	European Academy for Environmental Medicine
FDA	Food and Drug Administration (USA)
FDTD	Finite difference time domain
FCC	Federal Communications Commission (USA)
FMBC/FMBA	Federal Medical Biophysical Center of the Federal Medical Biological Agency (Russia)
GBM	Glioblastoma multiforme/glioblastoma
GFAP	Glial fibrillary acidic protein
GSM	Global System for Mobile communications

GST	Glutathione S-Transferase
HAPS	High-altitude platform stations
IARC	International Agency for Research on Cancer
ICEMS	International Committee on Electromagnetic Safety
ICNIRP	The International Commission on Non- Ionizing Radiation Protection
ICRP	International Commission on Radiological Protection
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
IoT	Internet of Things
ISDE	International Society of Doctors for the Environment (Italy)
MIMO	Multiple Input Multiple Output
MMWs/mmWaves	Millimeter waves
MPD	Maximum permitted dose
MW	microwave
NGOs	Non-Governmental Organizations
NHL	Non-Hodgkin's Lymphoma
NIEHS	National Institute of Environmental Health Sciences
NIR	Non-Ionizing Radiation
NTP	National Toxicology Program
ORSAA	Oceania Radiofrequency Scientific Advisory Association
PD	Power Density
PHIRE	Physicians' Health Initiative for Radiation and Environment (UK)
PPE	Personal Protective Equipment
RAS	Russian Academy of Sciences
RF	Radiofrequency
RF-EMF	Radiofrequency-electromagnetic fields
RNA	Ribonucleic acid
RNCNIRP	Russian National Committee for Non-Ionizing Radiation Protection (also abbreviated as RNKZNI ofRusCNIRP)
SanPiNs	Sanitary-epidemiological regulations and norms (Russia)
SAR	Specific Absorption Rate
SEER-9	Surveillance, Epidemiology and End Results-9

SRC-FMBC	Russian State Research Center Burnasyan Federal Medical Biophysical Center (of the Federal Medical Biological Agency); also abbreviated as 'Burnasyan FMBC of FMBA'
TA	Total Antioxidant
TBARS	Thiobarbituric Acid Reactive Substances
UN	United Nations
μW	microWatts
WHO	World Health Organization

Introduction

For more than 30 years, the global community has been discussing the dangers of electromagnetic fields (EMFs) for public health. During this time, 2G, 3G and 4G technologies have already been used in the system of cellular communications, and now an expansion to this technology is planned under the banner of "5G". At the international level, many countries have established official committees, forums and public trust committees, and scientific alliances to address the perceived problems of the new expansion. A few examples of these committees are the International Advisory Committee for the WHO's International EMF Project, the International Commission on Non-Ionizing Radiation Protection (ICNIRP), the BioInitiative Working Group, and the International Commission for Electromagnetic Safety (ICEMS). Many others have also been established. ICNIRP has created a set of guidelines that define exposure limits that are supposed to protect the public against any possible adverse effects from upgrades. However, the ICNIRP limits are only based on short term heating effects and have been criticised from several quarters (as will be discussed more fully below).

The Russian National Committee on Non-Ionizing Radiation Protection (RNCNIRP) has been working to incorporate *non-thermal* safety factors to protect against *long-term health effects* from radiofrequency electromagnetic field exposures (RF-EMFs) into Russian safety guidelines for over 20 years. In Russia, "Sanitary-epidemiological regulations and norms" (or SanPiNs) are legally binding directives within public and occupational health and safety standards that are created to protect the long-term health and safety of the population. For non-ionizing radiation (NIR), the RNCNIRP made the decision to include the development of SanPiNs specifically for children. Based on health risk assessments and their recommendations, SanPiNs (2.1.8/2.2.4.1190-0) were developed for NIR in 2003. This Committee's risk assessment for the general public, as well as for children, has been sent by the WHO to many countries around the world.

Despite these efforts by the RNCNIRP, for exposures to the *non-ionizing* type of radiation that we use for wireless communications today (unlike low-dose *ionizing* radiation), we still do not have adequate information on which to base a public health risk assessment. It is our opinion that "self-interest" (on the part of the telecommunications industry and also of governments) has created discordant views on public health risks from our wireless communication systems. Any admission of risk could open up a Pandora's box of litigation. A number of industry-friendly scientists hold leading positions in reputable international organizations that have a predominant influence on standard-setting and RF-EMF protection policies. In addition, many industry-funded studies are conducted with the intention of obtaining non-significant results in order to counter independent research findings that show significant effects.

The concept of *radiosensitivity* that creates "critical organs" has been ignored as a basic principle in the radiobiological assessment of the dangers of cellular communication EMFs. The brain, the thyroid gland, the skin, the immune system, the reproductive system, and ontogenesis are all examples of radiosensitivity to NIR in the human body. There is the possibility that an accumulation of adverse bioeffects will result in cellular damage which, in turn, gives rise to long-term health consequences. These consequences could lead to the reduction of average life expectancy, increased risks from lifetime radiation exposures, and a variety of diseases. It must be recognised that children are an "at-risk" group, and as such, should be treated as a special category.

The introduction of cellular communications into our daily life has significantly polluted the natural electromagnetic background of our environment, and has considerably increased the impact of EMFs on all population groups including children. Unlike ionizing radiation that is found in nature, this RF-EMF is an artificially created radiation which has no health analogy for comparison that we can use to derive the risk to public health.

It is not possible to derive new risk factors by extrapolating low frequency exposures to high frequency exposures. However, there is reason to believe that adding high-frequency 5G radiation to the already complex combination of lower frequencies will contribute to negative consequences for both the physical and mental health of the population.

5G technology significantly complicates existing approaches to hazard assessment and makes it problematic to protect the population from lifelong (chronic) exposure.

In many countries, there is a complete disregard for the precautionary principle proposed by the WHO (Precautionary policies and health protection, 2001). At the same time, we have the intermittent appearance of publications stating that wireless communication is harmless for public health. In the US, the previous Trump administration declared that 5G technology was to be a priority in the national security program (Crichton, 2017).

It should be noted that the introduction of the 5G standard is not just the "next" generation of mobile communications (after 2G, 3G and 4G) created for our ease and convenience - it is also being used for the development of a new type of military technology in the United States, as well as for possible "crowd control" applications (Active Denial Systems).

In the United States, the FCC has allocated the millimeter wave spectrum for the 5G standard (0.6 GHz; 24.25 to 25.25 GHz; 27.5 to 28.35 GHz; 37 to 40 GHz; and 64 to 71 GHz) without conducting any preliminary research on the safety of these frequencies for the public.

Unfortunately, controversy regarding the health impacts of modern wireless technologies has continued for more than 30 years. The problem is now further complicated by the introduction of the 5G Super High Frequencies (SHF), the millimeter waves (MMWs) that will be used in addition to the already Ultra High Frequencies (UHF) of previous technologies. Assessing the impact of this mixture of RF-EMF frequencies becomes even more complicated, especially for epidemiologists, since, after the introduction of 5G, there will be no control population groups that have *not* been exposed to EMR. Also, it should be recognized that RF-EMF has a synergistic effect, whereby the combination of bio-toxins, together with bioeffects from EMFs are seen to amplify health effects (Kostoff & Lau, 2017).

The 5G communication standard is not only *quantitatively* different from 2G, 3G and 4G, but also varies *qualitatively*. It is a mistake to assume that the introduction of the 5G communication standard is just a further "innocuous" rise in the level of radiation exposure for the population. The use of millimeter wave technology increases the possibility of substantial health impacts because of constant exposure to the skin and the eyes, which we identify as being critical organs due to their potential for radiosensitivity. A new radiobiological approach to 5G hazard assessment is required.

The authors and translators of this book are convinced that the true consequences for the health of all population groups, and for our existing way of life, will only become known when several generations have passed.

Part One: Identifying the Potential Health Risks of the 5G Standard

A new fifth generation of cellular communication

5G is planned to be the foundation for the creation of a "European Gigabit society" by 2025. The creation of the Internet of Things (IoT) is being marketed on the basis of its potential to create a better, more comfortable and convenient way of life. The IoT network will use a new generation of shorter high-frequency 5G millimeter waves for its communications and will connect a great variety of objects to the Internet. It is estimated that there are likely to be between 10 and 20 billion connections to refrigerators, washing machines, surveillance cameras, self-driving cars, buses, roadways, baby diapers, and so on. Antennas and devices will continuously be in close proximity to the user's body. All this will lead to a far greater cumulative EMF exposure impact on the population, both in terms of quantity (more exposure) and time (long-term).

5G base stations with micro antennas, known as *small cells* (see the video: "5G Bytes: Small Cells Explained"[1]), will surround people everywhere. These antennas can be just millimeters in size. They will be located on the pre-existing base station infrastructure used by 2G, 3G and 4G. They will be in high density areas such as shopping malls, workplaces and hospitals. To successfully deliver their signals, they will need to be mounted on electrical power poles, lampposts and other street facilities, at all intersections, on stairwells, in apartments, on each floor of schools and office buildings, and so on. The new antennas will blanket human populations with more electromagnetic radiation. According to Moskowitz (2017), California alone will require an additional 50,000 base stations.

The 5G technology allows for a dramatic increase in the volume and speed of the transfer of data. However, delivery of the signal to the consumer will entail the densification of antennas (called small cells) in close proximity to the user. In addition, in support of the

[1] Video accessible at IEEE Spectrum webpage: "5G Bytes: Small Cells Explained", published 19 August 2017, https://spectrum.ieee.org/video/telecom/wireless/5g-bytes-small-cells-explained

new system, to ensure the stability of communications throughout the entire planet, around a thousand satellites have already been deployed in space. Thus, the new 5G system introduces new RF exposures to the planet which must be addressed in terms of human health.

When it comes to potential health effects, a major problem is the difficulty of measuring and monitoring millimeter waves. There is also no agreed methodology for determining what levels of exposure to this radiation would be safe. Organizations such as ICNIRP and the FCC do not recognize the wider dimensions of risks and thus there is no management of these risks. Instead, there is only *guesswork* about the biological impacts of a lifelong exposure to millimeter waves, both for humans and for the world's ecosystems, and this guesswork is based on assumptions—assumptions that may not be accurate.

Unlike the existing 2G, 3G and 4G wireless communication technologies, the *fifth-generation* technology standard (5G) will additionally use the *millimeter wave* (MMW) section of the radiofrequency (RF) part of the electromagnetic spectrum. The term "millimeter waves" refers to extremely high-frequency (30 to 300 GHz) electromagnetic vibrations. (For a concise explanation of the use of MMWs in 5G see the IEEE video "5G Technologies: Millimeter Waves Explained"[2].)

We know that millimeter waves are strongly attenuated (or absorbed) when propagated in the earth's atmosphere. An example of this attenuation is the disruption of television signals from satellites by heavy storms. Signal attenuation is caused by the resonant absorption of wave energy in atmospheric gases, and it is highly dependent on weather conditions (e.g. rain, fog, snow and pollution). Furthermore, terrestrial millimeter wave radio systems are characterized by a short range of only hundreds of meters instead of kilometers, due to obstacles like vegetation and buildings. The attenuation is a direct result of the smaller size of the 5G MMW EMF wavelength, which has less power of penetration than the 3G or 4G EMF waves. This is the reason why 5G needs to be deployed on electrical street poles.

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[2] YouTube video: "5G Technologies: Millimeter Waves Explained", [IEEE Spectrum], May 9, 2017, https://www.youtube.com/watch?v=aacnhn8IcHI is an extract from the video "Everything You Need to Know About 5G", [IEEE Spectrum], Feb 7, 2017), https://www.youtube.com/watch?v=GEx_d0SjvS0

As a consequence of attenuation and the relatively short range of millimeter wave signals, if they are used to cover a certain area, then hundreds of antennas and an increased number of base stations (BS) will be needed. For example, if a 5G base station has a cell radius of 20 meters, about 800 base stations per square kilometer would be needed, located in close proximity to the consumer 24-7. Many 5G antennas will need to be located just a few meters away from residential homes. This is in sharp contrast, for example, with 3G and 4G, which use *large* cells that range from 2 to 15 km or more, allowing a larger area to be covered by fewer base stations.

The 5G base stations will use a targeted beam of RF-EMF to reach the user through a phased array system. This will allow targeted beams of RF to be directed at the cell phone user. These highly polarised beams of RF-EMF are similar to laser beams which are focused and coherent beams of visible light. Currently the RF-EMF mobile phone or Wi-Fi radiation radiates in all directions (isotropically), and the intensity drops off in accordance with the inverse square law. This is not the case with targeted MMW beams. This new source of RF will be in addition to the radiation doses we currently receive from existing technologies. Moreover, wireless *devices* will support several standards at the same time and will be able to work synchronously for different tasks. This will create a new electromagnetic environmental "soup" that we will live in continuously.

Due to their smaller wavelength, millimeter EMF waves are also easily absorbed in tissues, with a penetration depth of only 1–2 mm (maximum). Given this fact, only the skin of the body and the superficial mucous membranes, for example, the sclera (white part) of the eyes are expected to be affected.

In our opinion, when assessing the risk of MMWs for public health, it is necessary to consider the skin and the eyes (in particular, the sclera of the eyes) as new critical organs (a full discussion of this topic is given in the sections below).

Today, satellites are considered an integral part of the launch of 5G and the IoT. To ensure global connectivity, in March 2018, the US Federal Communications Commission (FCC) granted approval for SpaceX to launch 4,425 satellites around the Earth. In 2021, with already over 1,300 satellites in orbit, SpaceX was granted permission by the FCC to launch 2,814 more STARLINK satellites into lower orbits. SpaceX has asked the FCC to approve up to 12,000 satellites so as to provide "ultra-fast, lag free 5G”. This will mean that a billion ground-based antennas will be required. The plan is to have fast-access internet from space to every square meter of the earth.

Due to absorption in the atmosphere, mostly clouds and rain, the power of the MMW signal from satellites can be reduced by almost ten times. To overcome this limitation, phased arrays are being used so as to sufficiently concentrate the beams of rays to ensure that they reach the ground. The satellites will be located in two orbital planes at altitudes of 340 km and 1,100 km. Military satellites already use phased arrays. In addition to the new satellite telecommunication infrastructure, high-altitude drones or High-Altitude Platform Stations (HAPS) will be deployed to permanently reside in the stratosphere and act as relay stations for communication satellites. As a result, there will be Internet connectivity throughout the planet.

The effective outcome of the deployment of the new 5G infrastructures will be that the entire population of the earth will be trapped for life in an electromagnetic grid of millimeter wave radiation, from which no one will be able to escape (see Figure 1).

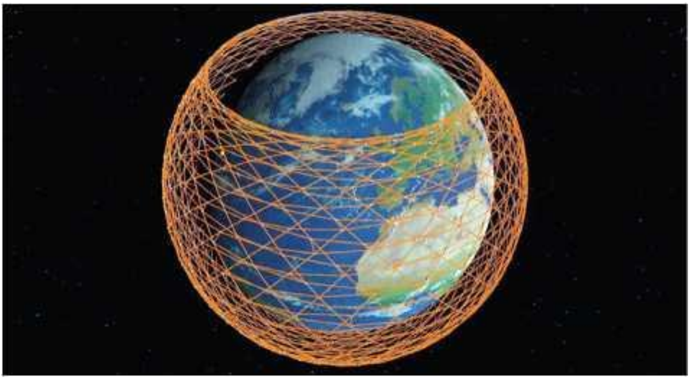

Figure 1: An artist’s rendition of the global 5G Internet

While the 5G infrastructure development forges ahead, the telecommunications industry resorts to partisan lobbying and, at the same time, actively tries to shape public perceptions of 5G technology as being “harmless” for public health. Despite the incredible pace of change in our electromagnetic environment, it was suggested by Foster (2019) that authorities delay the revision of new protective standards: “First we need to see how this new technology will be applied, and how scientific data will develop". In our opinion, this statement is akin to calling for a "mass 5G experiment".

Keen for further growth, the telecommunications industry itself is appealing to the general public to adopt this technology faster without question or caution (Grigoriev, 2020). In a 2015 plea for caution, more than 260 scientists and doctors asked the UN to declare a moratorium on 5G deployment until industry-independent scientists can fully and objectively assess the health risks associated with the new technology (International Appeal, 2015). One of the authors of this book signed the appeal. Here follows an extract describing the rationale of the appeal:

> *Numerous recent scientific publications have shown that EMF affects living organisms at energy levels well below most international and national recommendations. Effects include increased cancer risk, cellular stress, an increase in harmful free radicals, genetic damage, structural and functional changes in the reproductive system, learning and memory deficits, neurological disorders, and negative effects on overall well-being. The damage goes far beyond the human race, as there is growing evidence of harmful effects, both on plants and on animal life.*

It is not just 5G frequencies that present health risks to humans, plants and animals. There is already a wealth of research pointing to harm from 2G, 3G and 4G frequencies.

In 2018, the US National Toxicology Program (NTP) published the results of a $30 million, whole-body, non-thermal animal study (Wyde et al., 2018), and reported finding "clear evidence" of carcinogenesis as a result of CDMA and GSM communication radiation. The NTP study was designed to represent the non-thermal exposures that a mobile phone user experiences when a phone is used near the body. The results showed increased risk of cancer in male rats and damaged DNA in both rats and mice of both sexes. The results of a further animal study conducted by the Ramazzini Institute in Italy then corroborated the findings of the near-field NTP study. The Ramazzini Institute study was a far-field study and represented the weaker radiation exposure levels of population groups living near base stations (Falcioni et al., 2018). Together these studies suggest that mobile phone and mobile based station signals are likely to cause cancer in humans.

The WHO's International Agency for Research on Cancer (IARC) classified radiofrequency radiation as "possibly carcinogenic to humans" in 2011. The increase in head and neck tumors in cancer registries being observed in many countries (Hardell, Carlberg, Hansson Mild & Eriksson, 2011) may be due to the increasing use of wireless devices. This increased risk is consistent with epidemiological case-control studies (Hardell & Carlberg, 2015) that found an increased risk of tumors in people who use mobile phones for a long period of time.

Moreover, there is strong scientific evidence that radiofrequency radiation causes neurological disorders (Hao, Zhao & Peng, 2015) and harm to the reproductive system (Vereshchako & Chueshova, 2017). The biological and health effects of 2G, 3G and 4G waves will be covered in more detail in Part Two of this book.

The volume of peer-reviewed scientific data on non-thermal bioeffects of the earlier wireless technologies (as shown by the Oceania Radiofrequency Scientific Advisory Association [ORSAA] database [Leach, Weller & Redmayne, 2018]) suggests that exposure to microwaves and millimeter waves used in 5G is also likely to be harmful.

Nonetheless, the implementation of the 5G standard in cellular communication structures in many countries is proceeding aggressively and rapidly, with a complete absence of rigorous pre-market biological testing that would be required for other consumer products.

The problem is that it is currently impossible to accurately model or measure the actual health effects of MMWs, so as to reliably assess the danger. As there are no long-term observations, researchers do not know the possible long-term consequences and this is why the world must proceed with caution.

Characteristics of millimeter wave electromagnetic fields

The millimeter wave electromagnetic fields used in the 5G system are very different from RF-EMF fields surrounding previous generation mobile technologies. This is due to the complexity involved in forming a beam of millimeter waves for transmission in both directions (as shown in the video: "5G Technology: Full Duplex Explained"[3]) i.e. from the base station to the client terminal and the signal's return. These are called *uplink* and *downlink* signal beams. Although the beams are highly focused, they change rapidly as they move in both time and space, and are therefore unpredictable.

5G technologies are comprised of modulated signals with increased data streams using multiplexing, where spatial multiplexing refers to simultaneous and multiple messaging sent to several users. They also use beamforming, (as shown in the video: "5G Technologies: Beamforming Explained"[4]) which enables massive MIMO (Multiple-Input and Multiple-Output) (as shown in the video: "5G Technologies: Massive MIMO Explained"[5]), enabling many messages to be transmitted at once without interference. This makes the 5G waveforms very complex, with their biological effects untested.

MMWs generate significantly higher intensity or (surface) power density (PD) and absorbed radiation (see discussion on SAR below) than existing cellular technologies of 3G and 4G standards. This increased exposure can be caused not only by the use of higher frequencies in 5G. In addition to shorter wavelengths, because the beams are polarised, they can constructively interfere or add-up as well as subtract. This makes the electromagnetic environment a continuously changing and volatile mix of signals. The dynamic nature of RF-EMF radiation means that complex interference effects can be created, especially in densely populated urban areas.

These new technologies may increase the risk of overexposure from short bursts of intense radiation. Some scientists are concerned about the short-term effects of intense heating (e.g. Neufeld and Kuster, 2018).

Herein lies a big problem: currently it is impossible both to accurately model or measure 5G emissions into the environment. Likewise, it is also extremely difficult to

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[3] YouTube video: "5G Technology: Full Duplex Explained", [IEEE Spectrum], April 21, 2017,

[4] YouTube video: "5G Technologies: Beamforming Explained", [IEEE Spectrum], July 28, 2017, https://www.youtube.com/watch?v=OidnBOcXvic

[5] YouTube video: "5G Technologies: Massive MIMO Explained", [IEEE Spectrum], August 3, 2017, https://www.youtube.com/watch?v=QVNmaISVPCg

characterize the interaction of MMWs with biological structures.

The dosimetry underpinning current guidelines

In 2020, after 22 years, ICNIRP released its new set of guidelines (ICNIRP, 2020). The main changes from the previous recommendations (ICNIRP 1998) relevant to 5G and the spectrum above 6 GHz are: (a) adding a limit on whole-body exposure levels when averaged over 30 minutes; (b) adding a limit for short-term exposure to small areas of the body (to less than 6 minutes); and (c) reducing the area of the body over which maximum allowable exposures are calculated (to 4 cm^2). These ICNIRP updates have maintained historical methods for dosimetry and exposure calculation that have serious shortcomings; in particular, for millimeter waves, as described below.

Dosimetry is used in both ionizing and non-ionizing radiation to determine and measure the amount (or dosage) of radiation energy that is absorbed in tissue. To create standards for safety, measurements must be taken in real world settings, and the values found in those settings must not exceed certain levels (called "limits")

Based on global experience with ionizing radiation, the only "yard-stick" for measuring the effects of non-ionizing radiation is the absorbed dose rate or specific absorption rate (SAR). The SAR for any given exposure event is the amount of energy absorbed by a unit mass of tissue (expressed "per kg") within a certain time interval. Thus, SAR is typically measured using the SI units of *W/kg.*

National and international regulators set SAR limits for the public so as to avoid excessive local tissue heating and whole-body heat stress respectively. The goal is to avoid biological consequences in response to a radiofrequency-induced increase in body temperature of 1°C or more occurring over an average exposure time of six minutes. Such a core body temperature increase is deemed by the American Conference of Governmental Industrial Hygienists (ACGIH, 2017) to be unacceptable, creating potential adverse health effects due to heating.

The current ICNIRP guidelines are based on the levels at which harm is expected to occur, which are then divided by a safety factor to set the limits for each frequency range. For clarity, the discussion below is based on the levels at which ICNIRP deems harm to occur.

ICNIRP make the assumption that harm due to whole body exposure occurs at a SAR threshold of 4 W/kg (when calculated as the average energy absorption by the whole body as averaged over 30 minutes). For specific areas of the body, however, ICNIRP considers that larger temperature increases of 2°C and 5°C created by SAR values of 20 W/kg (head and torso) and 40 W/kg (limbs) respectively, are acceptable levels of harm.

When it comes to *devices*, regulatory authorities specify a maximum permissible dose (MPD) using SAR levels, and therefore modern wireless devices must all have their own SAR ratings. That is, the 2G, 3G and 4G signals emitted by devices are required to comply with the ICNIRP or FCC SAR limits.

However, SAR cannot be calculated for shallow MMW penetrations from local near-field exposure. Instead, the power density from a far-field plane wave is used instead of SAR so as to specify limits for local exposures to MMW. The unit of measurement used is power density or intensity, measured in SI units of W/m^2. It indicates the estimated allowable incident exposure from the far-field wave approximation.

For 5G millimeter waves 6 to 300 GHz and for localised areas of skin, ICNIRP estimates that harm occurs at power density exposures of 200 W/m^2 (calculated as the average power density absorbed over 4 cm^2 and over 6 minutes). ICNIRP has not distinguished between head, torso and limb exposures when defining these levels. For frequencies above 30 GHz, the calculation of absorbed energy is averaged only over 1 cm^2 and cannot exceed 400 W/m^2.

Use of far field power density approximations is unreliable, because the distribution of the electric and magnetic fields and the absorption of tissue are more complex in the near field than can be described by a far field approximation (Wu, Rappaport, & Collins, 2015). For example, for exposures to the eyes from 5G mobile phones with many antennas held close to the head, each antenna has its own field, which together create a complex electromagnetic field that is not well approximated by a plane wave or by the average value. Moreover, many factors, such as frequency, tissue density and conductivity add complexity to the uncertainties involved in setting exposure recommendations.

The need to re-evaluate 'heating effect' standards and procedures

The current exposure guidelines use SAR and power density for dosimetry and averaging methods for determining exposures. Both of these protocols have inbuilt flaws that ignore non-thermal and stochastic effects.

The problem with using SAR as the main dosimetry measure is that it is only based on the somatic effects of heating (Panagopoulos, Johansson, & Carlo, (2013). There are other effects that occur at SAR levels below those that cause heating, that creates the risks associated with *non-thermal effects*. Non-thermal effects cannot be ignored when determining the dosimetry methods and principles for setting radiation protection limits.

Similar to low-dose ionizing radiation where there are stochastic effects, we cannot ignore the stochastic effects that occur in non-ionizing radiation. These create non-linear effects that are not well approximated by averaging over time and space.

So far, the only alternative methods of MMW dosimetry being proposed are based on theoretical calculations and numerical modelling (Pawlak et al., 2019). For example, Thors et al. (2016) have presented a model for estimating time-averaged realistic maximum power levels for 5G base stations. A close measurement system and a three-dimensional field reconstruction method has been designed for predicting the power density of MMWs in the near-field (Douglas et al., 2018). These are merely theoretical models and it is only recently that the first experimental studies have been conducted to measure the level of MMWs emitted by 5G base stations (Adda et al., 2020).

Several pioneering studies have suggested that the energy from millimeter waves that is absorbed by the skin exceeds the recommended ICNIRP guidelines. The results of these studies, presented below, justify the need for a review of the new ICNIRP guidelines.

Gandhi and Riazi (1986) focused their research on characterizing the absorption of microwave radiation in the human body and assessing the significance of the biological consequences. The values they obtained are highly significant and can be used for predicting the risk to human populations with lifelong exposure to MMWs. Calculations for frequencies ranging from 30 GHz to 300 GHz, gave depths of penetration of MMWs into the skin varying from 0.78 mm to 0.22 mm, with corresponding surface values of the absorbed dose (SAR) varying from 65 to 357 W/kg. The PD of the incident radiation energy flux used for these calculations was 5 mW/cm^2, corresponding with the threshold limits specified in the guidelines of the American National Standards Institute (ANSI). At this power density, Gandhi and Riazi calculated SAR values for MMWs at the skin surface that were far higher than the FCC standard of 1.6 W/kg.

According to Gandhi and Riazi, since most of the absorption of millimeter waves is in the area of the skin, the heat reception in the skin from the absorbed energy will create similar sensations to those that occur from exposure to infra-red radiation. For infrared radiation, the whole-body heat perception threshold is about 0.67 mW/cm^2 (Hardy & Opel, 1937, adapted by Gandhi and Riazi, 1986). Based on this experimental work, Gandhi and Riazi calculated that exposure to large areas of the body (over 40 cm^2) to millimeter waves with an absorbed PD of about 8.7 mW/cm^2 may result in a "very warm-hot" sensation with a delay of 1.0±0.6 seconds. The whole-body exposure allowed by the new ICNIRP guidelines is set at 1 mW/cm^2, when averaged over 30 mins. If a larger spike of energy (e.g. 8.7 mW/cm^2) occurred for 1 second, this may cause a "very warm-hot" sensation. However, it would not officially violate the ICNIRP limit, because the spike value would be smoothed down by the averaging calculation used by ICNIRP to determine the official level of exposure.

In the same work, Gandhi and Riazi point out the need to evaluate the *eye effects* of MMW exposure They estimated power absorption for the eye of 15-25 mW for an incident PD of 10 mW/cm^2, where injury from MMWs has been found in rabbits' eyes after half an hour of exposure. An irradiation intensity of 0.7 mW/cm^2 can cause a sensation of heating of "very warm or hot" within a second (Hardy & Opel, 1937, adapted by Gandhi and Riazi, 1986). However, the new ICNIRP limit is 2 mW/cm^2 or 20 W/m^2 for exposures to the eye (set so as to ensure the temperature does not increase by more than 2 degrees). Thus, the official limit is higher than the level at which sensations of heating have been predicted by Gandhi et al, giving concern for the safety of the eye under the new guidelines.

Om P. Gandhi, Professor of the Department of Electrical and Computer Engineering, University of Utah, USA

Potential for unacceptable temperature increases

Neufeld and Kuster (2018) have modelled heating effects on skin due to pulsed millimeter wave signals greater than 10 GHz. These authors devised a new approach to modelling such effects using mathematical analytical models of temperature oscillations corresponding to various energy doses. The modelling revealed how pulse trains (made up of very short but high-power data bursts) can create temperature spikes in localized areas of skin. This occurs because the intense energy from each pulse may be transferred to the skin within a very short fraction of the pulse time. The time needed for the dissipation of this heating effect is less than the time available before the next energy spike arrives at the skin surface. Successive intense spikes of energy (transferred to the skin from the pulsed waves) thereby rapidly build up heat in a local area of skin. In this way, 5G pulse trains can lead to local short-term temperature increases of up to 10°C on the skin of people exposed, which exceeds tissue damage thresholds.

Neufeld and Kuster clarified that the ICNIRP methods for calculating energy transferred—by averaging over a given time period—do not adequately restrict the intensity of any given spike. Their analytical modelling revealed how use of averaging can allow for ICNIRP-acceptable energy spikes, with a peak-to-medium ratio of 1000, which can cause permanent damage to skin tissue even after short exposures. The authors concluded that the parameters and procedures used by ICNIRP for calculating the safety thresholds for 5G radiofrequency exposure are therefore inadequate.

For example, current emergency broadband wireless devices operating at frequencies above 10 GHz can transmit data in packets from a few milliseconds to seconds. These signals could violate the allowable temperature increase if they comprised short but intense spikes of energy. Spikes of energy can also occur due to interference and interactions between signals from different RF sources, which can lead to short-term pulses with a higher power density than the average recommended ICNIRP values of 10 W /m^2 (Puranen, 2018).

The safety implications of signals in the frequency range above 6 GHz were further considered in the work of Neufeld, Samaras and Kuster (2020). The authors showed that the application of the new ICNIRP standard for pulsed fields with frequencies from 6 to 30 GHz can lead to unacceptable temperature increases. This may occur due to the way in which spatial as well as temporal averaging is used in creating the new ICNIRP threshold levels. The new ICNIRP spatial averaging area of 4 cm^2, although significantly reduced in comparison with the previous guidelines, still does not prevent high temperature increases in the case of narrow beams. A *single* pulse from a narrow beam can lead to an increase in temperature about 10 times higher than the temperature increase due to a wide beam or a plane wave. The current method of averaging over 4 cm^2 predicts a temperature increase for plane waves of 0.4°C. However, a narrow beam with a radius of 1 mm will have all the heat deposited in a much smaller area; therefore, the heating in that localized area would be much more intense. Furthermore, a *train* of pulses from a narrow beam would lead to an even greater temperature increase (almost 10°C).

These results underscore the importance of reviewing the methods used for calculating existing exposure guidelines. The Neufeld and Kuster (2018) paper showed that the *intensity of spiking* needs to be restricted, and the *allowable averaging times* need to be reduced for all millimeter waves. The Neufeld, Samaras and Kuster (2020) paper shows that *allowable averaging times and areas* need to be reduced to cater for narrow beams. These papers provide methods for defining parameters that could be used to create safety guidelines regarding heating due to millimeter waves.

The Neufeld and Kuster (2018) predictions were criticized by Foster (2019) as being unrealistic for existing technologies. However, radiation protection is not meant to focus on whether a technology can work effectively or not; it must instead focus on protecting the public from exposures that may eventuate from the anticipated use of such technology, and the consequential possible effects thereof. This requires the inclusion of precautions in the setting of the safety limits for those exposure regions of the body where long-term biological effects may result in possible detrimental health outcomes.

Neufeld and Kuster (2019) emphasised the need to anticipate changes that might be harmful for short-term exposures:

> *However, we strongly believe, particularly in view of the longevity of standards and rapid technological changes, that a standard should be intrinsically safe and consistent, rather than relying on implicit assumptions about current and future technological limitations… We are confident, however, that optimization of the parameters (averaging time and area, power and fluence limits, etc.) can result in guidelines that are inherently consistent and that minimally impact maximal use of the spectrum >6 GHz.* (Neufeld & Kuster, 2019, p 70-71)

In recent simulations, Kim and Nasim (2020) found that the use of a 5G cell phone at a frequency of 28 GHz can exceed the international radio frequency exposure standards set by ICNIRP if the mobile phone is held at a distance closer than 8 cm to the head or body. This means that a distance greater than 8 cm from the head will be required to meet the ICNIRP exposure limit. If the user is talking on a voice call with the phone to the ear, there will be direct radiation to the head which will exceed the exposure standards.

The above modelling studies reveal very real concerns regarding heating with millimeter wave technologies, that have not been investigated fully nor addressed adequately in the existing guidelines. Moreover, as described in section 1.2, short-term heating is not the only concern. The general population is typically also exposed to low-level radiation 24-7.

The new cellular technologies that use techniques such as adaptive antenna arrays and directional pattern formation create complex electromagnetic fields that pose problems for modern radio frequency measurement methods. New approaches for 5G standard dosimetry are necessary, for example, due to the significantly inflated exposures that can be created by new types of amplifying antennas for precise beam formation being used along with higher frequency bands.

At the very least, it is important to set the maximum local temperature increase for the skin and sclera of the eyes. As the above discussion shows, ICNIRP only takes the measurement of average values of radiofrequency radiation into consideration. It has been clearly demonstrated that using average values for radiation exposure can lead to an underestimation of the risk of exposure (Chavdoula et al., 2010). Moreover, the analytical models described above showed how the current spatial and temporal averaging methods are not good proxies for how energy is deposited into the skin. Better methods for approximating the heat energy deposited into the skin have been provided: in particular, for exposures in the near-field, relevant to mobile phone use (Neufeld, Carrasco, Murbach et. al., 2018; Neufeld and Kuster, 2018). These methods need to be included to inform future calculations of safety limits regarding heating due to 5G radiofrequency exposures.

In concluding this section on the need to re-evaluate heating effects, we would like to draw attention to the view of Professor James C. Lin, the Chief Editor of the highly prestigious *Bioelectromagnetics* journal. Lin's view on MMW skin exposure sits in contradistinction to the approach of the FCC:

> *However, for exposures at higher GHz frequencies (millimeter waves and 5G), RF energy absorption tends to be more superficial and concentrated. Energy deposition could quickly occur in a smaller tissue area or mass to cause intense temperature elevation within a very short-exposure time period.* (Lin, 2019, p 89)

Professor James Lin, Chief Editor of the Bioelectromagnetics journal

The maintenance of outmoded standards

The Committee on Man and Radiation (COMAR) is a technical committee of the Engineering in Medicine and Biology Society (EMBS) of the Institute of Electrical and Electronics Engineers (IEEE). Its primary function is to examine the biological effects of wireless radiation. In 2020, COMAR published a statement, *Health and Safety Issues Concerning Exposure of the General Public to Electromagnetic Energy from 5G Wireless Communications Networks*. This statement contains four specific positions on the possible health consequences of exposure to MMWs from 5G technology (Bushberg et al., 2020). However, the COMAR position is very controversial. We consider it necessary to reproduce their "optimistic" position here, because it contributed to the development of the current standards, which were established in 1996:

> *First, unlike lower frequency fields, MMW do not penetrate beyond the outer skin layers and thus do not expose inner tissues to MMW. Second, current research indicates that overall levels of exposure to RF are unlikely to be significantly altered by 5G, and exposure will continue to originate mostly from the "uplink" signals from one's own device (as they do now). Third, exposure levels in publicly accessible spaces will remain well below exposure limits established by international guideline and standard setting organizations, including ICNIRP and IEEE. Finally, so long as exposures remain below established guidelines, the research results to date do not support a*

> *determination that adverse health effects are associated with RF exposures, including those from 5G systems. While it is acknowledged that the scientific literature on MMW biological effect research is more limited than that for lower frequencies, we also note that it is of mixed quality and stress that future research should use appropriate precautions to enhance validity*. (Bushberg et al., 2020, p. 236)

In harmony with COMAR, the new ICNIRP guidelines are based on the outdated hypothesis that the only critical effect of RF-EMF exposure relevant to human health and safety is that of tissue *heating*. This is the same position that ICNIRP has maintained for decades: that standards setting should focus on preventing the overheating of body tissue.

Furthermore, the new ICNIRP guidelines were established only for conditions of single and short-term exposure to MMWs (6 to 30 minutes), without considering the important role of the skin in maintaining a stable comfortable state for the human body. In our opinion, the need to define a standard that includes the critical organs - the eye (sclera of the eye) and the skin - has been ignored. Differences in the sensitivity of different areas of the skin, as well as special features of the skin of children, are not considered. It is of great concern that the biological effects of chronic exposure to MMWs on the skin have not been studied (see section 1.2.1 below for a more detailed discussion of these critical organs). MMW exposure to a large area of the body together with simultaneous exposures to RF-EMF from 3G, 4G and 5G technologies have also not been studied.

An opinion article by Swedish scientists Hardell and Nyberg (2020) sharply criticized the latest ICNIRP guidelines (which were still in proposal format at that time) and ICNIRP's attitude in ignoring bioeffects, as well as its failure to adhere to the precautionary principle in determining the 2020 recommendations.

The anticipation of undesirable and detrimental health effects is an important part of the radiation protection philosophy underpinning the actions of the International Commission on Radiological Protection (ICRP). Future planning using precaution is routinely adopted when setting risks for low-dose ionizing radiation. ICRP sets guidelines in an ethical manner, with caution being at the forefront of their philosophy.

In contrast, the ICNIRP adherence to accepting short-term heating as the only evidence of harm and their rejection of the evidence for non-thermal bioeffects leading to pathology is misplaced and simply wrong.

The current position of ICNIRP, as established in their new guidelines, leads us to believe that we are far from the ultimate goal of agreeing on standard and acceptable limits of MMW exposure for the public and the environment.
If we are uncertain on the health effects or stochastic risks associated with these low-level exposures, we must err on the side of caution. This is why Russia has set a prudent limit which is 100 times lower than ICNIRP.

In spite of the many shortcomings, many countries have updated their own standards to align with the new, more liberal ICNIRP guidelines. However, the main outcome of the recent US (FCC) review has been to maintain their original ICNIRP-based guidelines, merely extending them to millimeter waves.

Starting in 2016, the FCC had initially planned to adopt rules that would include the consideration of the use of wireless broadband operations above 24 GHz. By the end of 2019, new guidelines were announced that, according to the FCC, would protect people from RF-EMF and 5G radiation (FCC “Radio Frequency Safety”, 2019). These standards were adopted under pressure from the U.S. Centre for Devices and Radiological Health (CDRH) and its parent organization, the U.S. Food and Drug Administration (FDA). The FCC simply re-affirmed the previous limits of exposure to radiofrequency radiation. Furthermore, the FCC considered it valid to extend the old RF-EMF exposure standard to include all frequencies up to 100 GHz (i.e., MMWs and 5G technologies).

In this regard, for mobile phone-related exposures, the US FCC standards have maintained the previous limits such that the amount of electromagnetic energy deposition that may occur to local areas of body tissue is 1.6 W/kg, while 0.08 W/kg is allowed for whole-body irradiation. (Note that the FCC averages SAR over 1g rather than 10g of tissue, so it is more conservative than the current ICNIRP standard.)

Overall, the outcome of the recent US FCC review process has been to change nothing, even though it had been 22 years since the regulations were last updated. Both the nature and magnitude of public exposure conditions have changed enormously in this time. Furthermore, two more decades of scientific papers showing risks of harm have had no impact on the FCC guidelines.

Questions raised regarding these decisions have been acknowledged by ICNIRP Vice Chair Eric Van Rongen, who believes that the new FCC guidelines, which took seven years to develop, are more appropriate than the organization's first guidelines, since they include the higher frequencies used for 5G services.

> *We know parts of the community are concerned about the safety of 5G and we hope the updated guidelines will help put people at ease. The guidelines have been developed after a thorough review of all relevant scientific literature, scientific workshops and an extensive public consultation process. They provide protection against all scientifically substantiated adverse health effects due to EMF exposure in the 100 kHz to 300 GHz range.* (ICNIRP media release, 2020)

Supporters of stricter recommendations on radio frequencies from the United States were the American Academy of Pediatrics, the American Academy of Environmental Medicine, and the California Brain Tumor Association. Many forums in other countries and in the European Union (EU), as well as our country, Russia, have also supported stricter guidelines for many years (Grigoriev, 2001, 2006, 2014, 2018).

On September 2, 2020, the Health Council of the Netherland's Committee on Electromagnetic Fields (EMV) published an opinion statement, *5G and health* (2020). The Committee considered that "there has been little research on the hazard of frequencies around 26 GHz and does not recommend using this frequency band until the potential health risks have been investigated". In their opinion, it cannot be ignored that the incidence of cancer, reduced male fertility, poor pregnancy outcomes and birth defects may be associated with exposure to RF-EMF. At the same time, they indicated that the relationship between RF-EMF exposure and these diseases is not proven.

Further, the Dutch Committee recommended that the latest ICNIRP guidelines be used as the basis for exposure policy in the Netherlands. However, the Committee made the following recommendations: “Since it cannot be excluded that exposure to MMW in accordance with the latest ICNIRP guideline may also affect health, the Committee recommends that caution be exercised and that exposure be kept at a reasonably achievable low level.”

The above excerpts from the Dutch Health Council Committee’s statement clearly show the Committee’s dilemma. On the one hand, the Committee stated that it agreed with the views of ICNIRP, but on the other hand, it recognized that it did not have sufficient evidence to exclude possible consequences. From our point of view, the divergence of opinions in the Dutch Committee on Electromagnetic Fields concerning the possible health effects of EMF and safe radiation protection standards does not contribute to a real solution to the problems of electromagnetic safety or protection for the general public.

It should be noted that Van Rongen’s opinion above regarding the FCC guidelines was in contradiction to the conclusion of the Dutch Committee in their published opinion statement, that not enough research has been done and possible health effects exist. Furthermore, an observer from the Dutch company “Agentschap Telecom” (which is part of the Ministry of Economic Affairs and Climate) was present during the preparation of the Dutch Committee’s opinion. This situation occurs frequently, that representative of telecommunication companies are involved in discussions related to the assessment of RF-EMF health effects for humans (Grigoriev, 2006).

Similarly, the ICNIRP position can be explained by the make-up of members, who are ardent supporters of the notion of complete safety of RF-EMF exposure to human health. ICNIRP has promoted this position for many years. ICNIRP is a non-governmental organization (NGO) based in Germany that receives support from various national ministries and international agencies. A number of the ICNIRP scientists responsible for setting radiation protection limits appear to have a financial interest in the telecommunications industry.

ICNIRP members persist in arguing that the thousands of peer-reviewed studies that have found biological or medical consequences from chronic exposure to non-thermal EMF levels (Leach & Weller, 2016) are insufficient to warrant stricter safety regulations.

The Vice Chair of the Commission, Eric Van Rongen, published his opinion in the Bioelectromagnetics Journal in 2004 on the assured safety of exposure to cellular RF-EMF for children (Van Rongen, 2004). Professor Grigoriev, in the same journal, criticized Van Rongen's point of view, noting that it contradicted the WHO's opinion on children's vulnerability to environmental factors (Grigoriev, 2004).

Professor Grigoriev had been in contact with Van Rongen many times; for example, when working for the International Electrotechnical Commission (IEC) and the Advisory Committee of the WHO's International EMF Project. However, attempts to defend the point of view of scientists in Russia and other countries about the higher radiosensitivity of children to RF-EMF have been dismissed.

On October 6, 2020, Dr Dariusz Leszczynski, a well-known expert in the field of radiation safety and an internationally recognized expert on the impact of EMF on public health, composed an open letter to the ICNIRP management, posing a significant question that can be paraphrased as: On what scientific basis can you continue to support a guideline that has essentially remained unchanged since 1996 and apply these guidelines to the introduction of 5G in wireless technology? (Leszczynski, 2020). Dr Leszczynski expressed his concern that the ICNIRP 2020 guidelines claim to ensure the health and safety of any user exposed to RF-EMF, regardless of age or health status, or whether the exposure is acute, chronic, or whether it lasts a lifetime.

In the letter, Leszczynski questioned the ICNIRP assurances, asking:

- on what basis can ICNIRP guarantee that every user is fully protected when there is not enough research on age- and health-status dependency for exposure to RF-EMFs;
- how can ICNIRP guarantee that the reduction factors included in the guidelines are correct when there are no such experimental studies and the safety provided by the guidelines is purely an assumption; and
- how can a user who starts using a mobile phone at the young age of five or six years, and will continue to use it for the next 80+ years, notwithstanding years of various health conditions caused by disease and aging, be sure of complete safety in the absence of research, based only on assurances that in turn are based purely on assumptions?

Leszczynski adds that "There are questions concerning scientific evidence that ICNIRP used to justify safety guidelines for the currently deployed 5G technology."

Dr Dariusz Leszczynski, PhD, Adjunct Associate Professor of Biochemistry, University of Helsinki

In spite of the above questions surrounding ICNIRP assurances, the current situation is that of active avoidance of the necessary discussions on long-term bioeffects and how this translates into health effects in the general population. This is a delay tactic that has been used by industry effectively for the last 25 years. It is part of a strategy by the telecommunications industry and other large financial structures that are focused on protecting profits.

In 2019, a group of investigative journalists from the EU examined the risks of 5G deployment and the adequacy of the ICNIRP safety guidelines (as they were then proposed) (Investigate Europe, 2019). Twenty-two articles were published in major newspapers and magazines in eight countries: France, Germany, Italy, the Netherlands, Norway, Poland, Portugal and the United Kingdom. This investigation termed the 5G deployment "The 5G mass-experiment" and concluded that ICNIRP is a "cartel" of scientists with links to industry who are actively influencing the safety guidelines. The journalists identified a group of 14 scientists who helped to create and uphold the guidelines of ICNIRP.

ICNIRP-industry ties have also been the subject of a report commissioned, coordinated and published by two members of the European Parliament: Michèle Rivasi (Europe

Écologie) and Klaus Buchner (Ökologisch-Demokratische Partei), and financed by the Greens/EfA group in the European Parliament.

Assessing the health risk for the population

To understand the interaction of MMWs with the body, we need to look, without presumptions, at the evidence. In particular, we must examine the biological functioning of the skin and the eyes, since these exposed and critical organs have a vital role to play in human health and wellbeing. Only then, will we be able to set appropriately protective exposure standards.

The assumption that has informed the current exposure standards is that the only biological action of MMWs on the body is absorption by the skin and sclera to a depth of 2 mm. Such a small depth of penetration may seem insignificant according to the old, simplistic photonic model of wave propagation. However, there is a complexity of biological interactions that are occurring within the skin layers and deeper into the body. To illustrate that such processes are possible, we can consider visible light, which is another form of non-ionizing radiation [NIR] with a shorter wavelength and even less penetration into the skin layers than MMWs. Visible light is involved in a myriad of physiological processes, and is very important to human health. It is thus plausible that MMWs are similarly biologically active. The true complexity of the interactions between MMWs and skin and sclera can only be understood by better understanding their components and processes, which are reviewed in the sections below.

The skin and the eyes (sclera) as critical organs

Skin

The skin is an integrated sensory system, acting as a complete receptive field and a biologically complex functional system. It plays a role in the body's system-regulating mechanisms and can be described as part of a bio-feedback 'intelligence' system, monitoring the external environment to ensure the comfortable state and optimal functioning of the human body. We know that the structural components and tissue features of the skin interact in a coordinated manner, directly or indirectly, and form an integrated system that perceives external environmental influences.

The skin is the largest organ of the body by area. The area of the skin in an adult reaches 1.5-2.3 m^2. The skin is rich in nerves and very sensitive. It connects to the brain and central nervous system (CNS) and blood vessels which in turn are critically interconnected with the other organs of the body (see Figure 2).

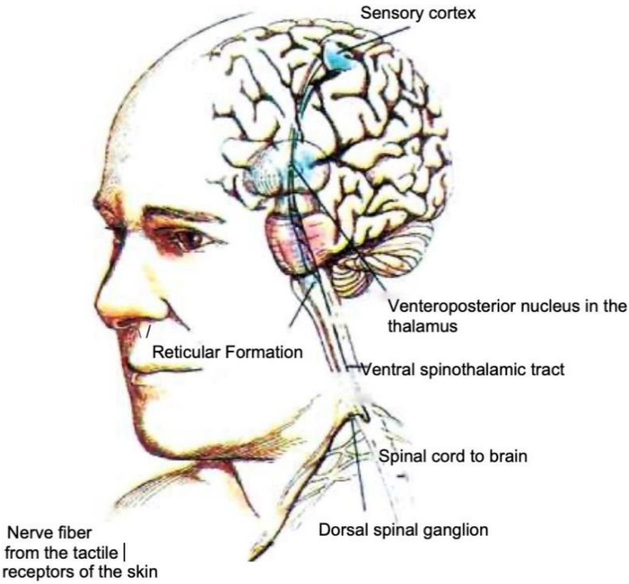

Figure 2: Sensory path of information from skin receptors to the brain

Receptors from the skin carry abundant innervation associated with both the central and autonomic nervous system. The autonomic nervous system (ANS), is a division of the peripheral nervous system that services smooth muscle and glands, and thus influences the function of internal organs.

The skin plays a role in the regulation of immunity and wound healing. The surface of the skin is a natural environment for thousands of different microbial species. The skin responds to and protects against mechanical and chemical factors, ultraviolet radiation, and the penetration of microbes and viruses into the body (Roosterman, Schneider, Bunnett, et al, 2005). This is important, since extreme effects on the skin can have catastrophic consequences.

The skin performs endocrine functions, and produces vitamin D when exposed to sunlight. In addition, it is important for thermoregulation and a number of other bodily functions. As a part of the body's excretory system, the skin discharges toxins from the body and eliminates the waste produced by homeostasis.

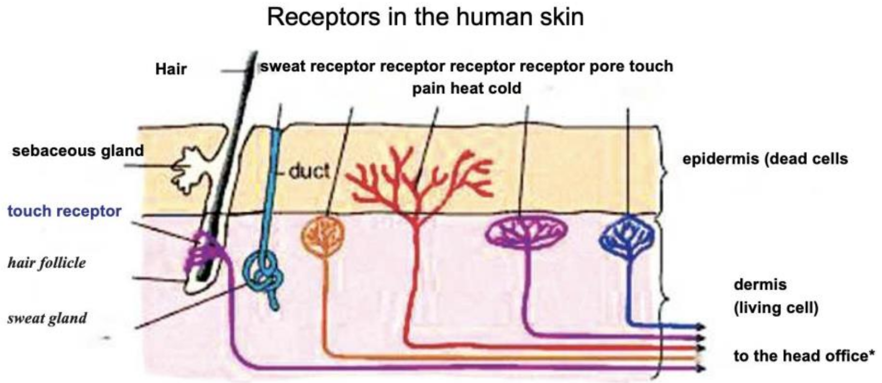

Figure 3: Receptors in the skin

Human skin consists of two main layers: the outer epidermis and the dermis as shown in Figure 3. The thickness of the human epidermis and dermis varies between 0.06-0.1mm and 1.2-2.8 mm, respectively. The stratum corneum (the uppermost horny layer of the epidermis) has a low water content (15-40%), and the total water concentration in the rest of the epidermis and dermis is 70-80%.

Since the MMW energy is very rapidly attenuated (absorbed) in tissue containing a high-water content, this leads to correspondingly high absorption coefficients of MMW electromagnetic energy in the deeper layers of skin tissue. If the water content of skin tissue is taken to be the major factor determining energy absorption, then it can be expected that the energy of millimeter waves easily penetrates the stratum corneum, but it is then quickly absorbed by the deeper layers of the epidermis and dermis and thus does not penetrate further into the body.

Until now, some scientists have focused solely on the thermoregulatory role of the skin when assessing the potential health risks of interaction between RF radiation and the human body. These scientists, particularly those with an industrial sciences orientation or more mechanistic background, tend to consider the skin simplistically as though it were an inert absorbent layer of sponge filled with water.

There are models of the skin that focus on structural aspects other than the water content of skin tissue, and therefore make different predictions. For example, Feldman and his colleagues have shown that the higher MMW frequencies are more efficiently absorbed from the air due to the electromagnetic characteristics of human sweat ducts (Betzalel Ben, Ishai and Feldman, 2018). First, increased conductivity occurs due to charged hydrogen ions (H+) moving along a chain of hydrogen rich water molecules, at the surface edges of the sweat ducts. This movement of hydrogen ions creates a current, leading to much higher levels of conductivity in the ducts (Feldman, Puzenko, Ishai, et al, 2008). Furthermore, these highly conductive sweat ducts are shaped as spiral antennas, with dimensions that maximally respond to MMWs in the sub-THz range (Hayut, Puzenko, Ishai, et al, 2012). The gain due to this antenna effect leads to concerning SAR levels of 2.2 W/kg at the higher 5G frequencies (Betzalel Ben, Ishai and Feldman, 2018). These authors have cautioned that such higher absorption of energy in the sweat ducts may lead to unforeseen non-thermal biological effects during the 5G rollout.

It is currently difficult to predict what kind of effects MMWs may have on the course of many skin diseases (e.g. eczema, psoriasis, abscesses), or on the development of tumor processes (e.g. melanoma, basal cell carcinoma, squamous cell carcinoma).

The abundant innervation from the skin to other parts of the body make the skin important to the reflexogenic zones, or Biologically Active Points (BAPs). These are areas of the body which, when stimulated, cause a definite unconditioned reflexive response. There are a variety of receptor zones in the skin, for which any resultant reflex reactions of the body from MMW exposures remain unknown.

MMW radiation is likely to affect nerve cells and other structures in the upper dermis. The sweat glands will also be exposed to radiation. It is possible that when exposed to MMW radiation, the sensitivity of the skin to ultraviolet radiation may change.

The skin is also constantly affected by various environmental factors, depending on the periods of exposure, which can change the normal physiological parameters of the skin. In addition, over different parts of the body, the skin will have its own characteristics and functional significance.

The structure and sensitivity of the skin changes significantly with age, so that the radiosensitivity of the skin of a child will differ significantly to that of an adult. Children's developing bodies are generally more vulnerable to physical environmental factors (Healthy environments for children: WHO backgrounder N°3, April 2003). Therefore, special attention should be paid to the skin of young people when assessing the danger of MMWs.

Thus, we must consider the critical role and functions of the skin as described above when assessing the potential consequences of MMW exposures. With its large surface area, the skin is a vulnerable interface with the environment. Thus, the skin is an important critical organ when considering a continuous lifetime exposure to MMWs for the population.

An analysis of the physiological effects of MMWs on the skin was presented in a review by Leszczynski (2020), who concluded:

> *the scientific evidence concerning the possible effects of millimeter waves on humans is insufficient to devise science-based exposure limits and to develop science-based human health policies. The sufficient research has not been done and, therefore, precautionary measures should be considered for the deployment of the 5G, before the sufficient number of quality research studies will be executed and health risk, or lack of it, scientifically established.*

A major obstacle in monitoring or studying the potential effects of MMW exposures to the skin is the difficulty in measuring the waves as they penetrate the skin. This is because there is a lack of instrumentation suitable and available for this purpose.

Many factors other than power density are relevant to determining the effects on skin. These include intensity, frequency, duration of exposure, polarization, pulsation, and modulation - all key parameters affecting the biological activity of EMF (Grigoriev, 1996; Grigoriev, 2017). Data has previously been obtained on the existence of so-called millimeter wave "windows", showing that various frequency ranges are more biologically active (Devyatkov, Betsky & Golant, 1986; Eidy, 1980). However, the differing impacts of these factors were not taken into account in the new ICNIRP guidelines. Thus, existing ICNIRP recommendations still only protect people from the heat created by acute EMF exposures.

Is clothing protective of skin?

It is important to assess the effect of clothing and clothing materials on the absorption of MMW radiation because these materials can potentially change the effects of MMWs on the skin. Clothing may act as personal protection. In this regard, Gandhi and Riazi (1986) obtained data on the MMW absorption coefficient for the human body with and without clothing. Their results showed that between 90 and 95 percent of the incident energy can be absorbed by the skin when wearing dry clothing, with or without an intermediate air gap; i.e., dry clothing absorbs only 5-10% of the incident radiation. Furthermore, dry clothing acts as an impedance-matching transformer, thereby increasing the transfer of the electromagnetic energy to the skin.

Bjarnason et al. (2004) measured attenuation in eight common clothing materials (wool, linen, leather, denim, silk, etc.) with a thickness of less than 2.2 mm in the frequency range from 100 GHz to 1.2 THz. For all measured frequencies below 350 GHz, none of the clothing materials investigated reduced the signal power levels by more than a half (3 dB). Similarly, Gatesman et al. (2006) measured attenuation of parallel and perpendicular polarised frequencies above 350 GHz in six different clothing materials (cotton shirt, denim, drapery, leather, sweater, and sweatshirt) with a thickness of less than 2.1 mm. Again, the materials did not weaken the transmitted power by more than 3 dB. The attenuation caused by other types of clothing still needs to be evaluated.

These results show that the attenuation of millimeter waves in most clothing materials is insignificant. In fact, clothing in direct contact with the skin can facilitate the transfer of electromagnetic energy to the body. It is important to assess the risk and not rely on unsubstantiated evidence that dry clothing completely absorbs millimeter waves and therefore only a small area of unexposed skin will be affected by the radiation. This needs to be confirmed experimentally. Naturally, the larger the size of the irradiated skin, the greater the significance for assessing the danger to the body.

Sclera of the eye

When assessing the risk of MMW exposure to a critical organ, it is necessary to consider the particular features of that particular organ. For the eye, it is relevant that there is a lack of optimal physiological mechanisms for removing excessive heat under conditions of overheating. Usually, blood flow removes heat, but the centre of the eye is devoid of blood flow. Thus, the eye becomes particularly vulnerable when exposed to MMWs.

The sclera of the eye (see Figure 4) is the opaque outer shell or "white" of the eyeball. The sclera covers the largest area of the eye; it has a dense composition which varies in different areas. The thickness of the sclera ranges from 0.3 to 1 mm. In children it is very thin, but it thickens over time.

The sclera has three layers: the episclera (outer layer), the sclera proper (or scleral stroma), and the lamina fusca (or inner layer). The episclera has a good blood supply, with both a deep and superficial vascular network. The richest blood supply occurs in the anterior (front) parts, because the vessels reach the anterior part of the eye, in the straight oculomotor muscles.

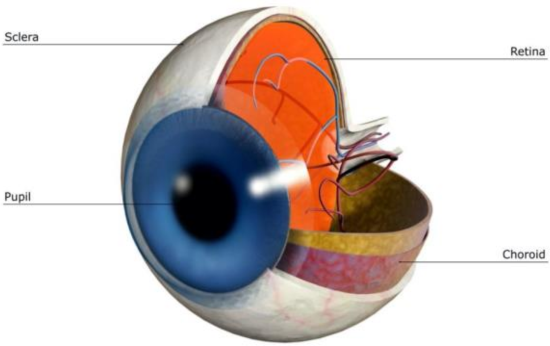

Figure 4: Sclera of the eye

The sclera itself consists of collagen fibers, the space between which is occupied by fibrocytes that produce collagen. The lamina fusca consists of thinned sclera fibers and elastic tissue. On the surface of the fibers are pigment-containing cells called chromatophores. These cells give the inner surface of the sclera a brown hue.

The body of the sclera contains several channels which conduct both the vessels and nerves that enter and leave the eye. The anterior edge of the inner side of the sclera has a groove measuring 0.8 mm. The ciliary body is attached to the posterior edge of the groove, and its anterior edge is adjacent to the Descemet membrane. The main part of the groove is occupied by the trabecular meshwork, above which is the Schlemm's canal. Due to the fact that the sclera of the eye is made up of connective tissue, it is subject to the development of pathological processes that occur in systemic diseases of the connective tissue (collagenosis).

Since the 1950's the eye has been deemed to be a potentially radiosensitive organ, due to scattered reports such as cataracts developing in a radar worker (Cook, Steneck, Vander, & Kane, 1980). Unfortunately, over half a century later, there are still only isolated studies of the effect of MMWs on the sclera of the eyes. Moreover, these studies were performed with short-term single irradiations only, at thermal levels of EMF intensity (Rosenthal et al., 1977; Kojima et al., 2009; Chalfin et al., 2000). The results of these studies are not sufficiently reflective of real-life conditions to accurately assess the risk for MMW exposures to the sclera.

Ghandi and Riazzi (1986) estimated a power absorption for the human eye of around 15 to 25 mW when the incident power density is 10 mW/cm^2. This is the amount of local exposure allowable by the current ICNIRP guidelines for workers; i.e., 100 W/m^2. This level of power absorption had been shown to cause epithelial and stromal injuries in rabbits' eyes, after one hour of exposure to MMWs (Rosenthal, 1977). While the rabbits recovered after the short-term exposures, these results suggest that the long term MMW exposures to which workers are subject may create damage to their eyes.

We have not found any research publications investigating the adverse effects of MMWs on the sclera of the eye, either in Russia or overseas.

The potential impacts for public health from a lifelong exposure to MMWs on the skin and sclera of the eyes remains unclear. The current standards do not sufficiently consider the vulnerability of the skin and the eyes to MMW exposures, or their critical importance to human health. The research base that is needed to justifiably derive and set such standards does not yet exist. There are no agreed methodological approaches, and no relevant experiments have been conducted. Methods to incorporate the bioeffect of MMWs on the sclera and cornea of the eye remain out of reach.

The problem of integrating the skin and eyes as new critical organs in the consideration of possible health effects of MMWs has therefore not been resolved.

It is our opinion that, because of the peculiarities specific to the absorption of MMWs, it is essential to define the skin and the eye as critical functional systems of the human body for MMW exposures.

Potential influences of MMWs on public health

The current 5G ICNIRP guidelines are problematic in that they only look at some acute thermal exposure effects on the heating of the body. However, members of the public are also exposed to non-thermal effects over a life-time.

As noted above, there are no studies that consider the chronic effects of MMWs on the skin and cornea of the eye. Consequently, we cannot yet assess the human health risks to these organs from a lifelong exposure to MMWs on the basis of objective data. However, we can consider the results available from previously published works investigating short-term effects of MMW exposures.

The number of publications around the world on this issue have increased significantly since 1996, when a specialized session of the Bioelectromagnetics Society (BEMS) was held on the subject of MMWs. The *Second World Congress for Electricity and Magnetism in Biology and Medicine*, dedicated to MMWs, was held in Bologna, Italy, in 1997. In 1998 an *EMF Science Review Symposium* was held in San Antonio, Texas. One of the authors of this book had the opportunity to participate in this workshop.

The sections below give an overview of the main effects of MMW on biological systems and health, from the perspective of Russian research. While Russia is known for its innovative therapeutic uses of MMWs, many other effects have also been uncovered by Russian scientists. leading to a deeper understanding of the interaction of MMWs with human systems, as well as greater concerns for public health.

Therapeutic uses of MMWs

MMWs were first used in clinical practice ("millimeter wave therapy of low intensity") in the 1960-80s in the USSR (as Russia was then known). This therapy application was based on the principle of resonant action of MMWs. Short-term and local irradiations were used (Devyatkov, Golant & Betsky, 1991). Betsky made a great contribution to the medical application of this biological effect.

Professor Oleg Betsky, Doctor of Physical and Mathematical Sciences

Positive therapeutic effects were obtained from short-term exposures to MMWs (Betsky, Kislov & Lebedeva, 2004; Betsky, Kotovskaya & Lebedeva, 2009). However, there were also side effects from MMW exposures including fatigue, drowsiness, and abnormal sensations (apparently caused by pressure or damage to peripheral nerves). Some somatic bioeffects under the influence of MMWs were described more than twenty years ago (Lebedeva, 1998). Unfortunately, the publication did not specify how much of the skin was exposed (the area), nor the location of the exposed skin itself.

Numerous *in vitro*, *in vivo* and theoretical studies have been conducted on the biological effects of MMWs, related to their extensive use in clinical practice, using short-term irradiations. These studies took place in several major institutes and universities in Russia; e.g. the Institute of Cell Biophysics of the RAS, the V. I. Vernadsky Taurida National University, and the Moscow State University.

These studies considered not only the effects of different conditions of short-term exposure to MMWs, but were also tasked with finding optimal modes for therapeutic use in medicine. The authors of this book are sceptical of the reliability of some of these studies which appear to have found optimal regimens for clinical practice. In each case, it seems that the authors may have had an *a priori* approach (or predilection) towards achieving positive findings. Similar experimental studies were conducted for other applications.

Effects of MMWs on biological systems

Pakhomov et al., (1998) reviewed the findings of the most significant publications concerning the effect of MMWs on cultured cells, isolated animal organs, and the human body. The studies that were reviewed demonstrated the effects of short-term exposure to MMWs as follows: Low-intensity MMW exposures (<10 mW/cm^2) resulted in effects on cell growth and proliferation, enzyme activity, the state of the cell's genetic apparatus, the function of excitable membranes, peripheral receptors, and other biological systems. In animals and humans, short-term but local exposure to MMWs stimulated tissue repair and regeneration, eased stress reactions, and led to demyelination of nerve cells (Pakhomov et al., 1998).

At the reception of Academician Leonid Andrey Ilyin From left to right: Andrey Pakhomov, Vladimir Stepanov, Yuri Grigoriev, Michel Morphy, Leonid Ilyin

Simko and Mattsson (2019) analyzed 94 publications that focused on the effect of MMWs *in vivo* and *in vitro* in acute exposure experiments. This review looked mainly at studies conducted in the frequency range from 30.1 to 65 GHz. Each study considered factors such as frequency, duration of exposure, power density and other radiobiological criteria for evaluating bioeffects. Of the *in vivo* experiments, 85% percent showed a response to exposure, while 58% of the *in vitro* studies showed a response. However, there was no marked relationship between the outcomes and the power density, the duration, or frequency of the MMW exposures. According to the authors, the analyzed studies do not provide adequate information for a meaningful assessment of the safety of MMW radiation exposures.

In the late 1970s, Dardalhon et al. (1979, 1981) had concluded that there was an absence of mutagenic effects from MMW radiation. However, a number of studies have shown that MMWs can affect the structure and function of the chromosome (see mentions of DNA in sections 2.1.1, 2.2 and 2.2.4).

Effects of MMWs on cells and micro-organisms

According to several authors, a large number of cellular studies show that MMWs can change the structural and functional properties of cell membranes, affecting the plasma membrane either by changing the activity of the ion channels or by modifying the phospholipid bilayer. These are accompanied by a change in the ionic conductivity of cell membranes and a rapid degeneration of ion channels causing leakage or blockage. Zhadobov et al. (2006) suggested that exposure to the millimeter wave band at 60 GHz at levels close to typical wireless communication systems (0.9 mW/cm^2) could cause an increase in lateral pressure in artificial membranes. Experiments by Ramundo-Orlando, Gallerano and Stano (2007), Ramundo-Orlando, Longo et al. (2009) and Ramundo-Orlando (2010) focused on the impact of low-level MMW exposure on cell membranes (<10 mW/cm^2).

These works also show how MMWs can alter the intracellular activity of calcium. As a consequence, MMWs also alter some cellular and molecular processes that are themselves controlled by Ca^{2+} dynamics. The effect of MMW radiation on ion transport could either be a consequence of direct effects on membrane proteins, and/or the organization of the phospholipid domain. Water molecules appear to play an important role in these biological effects of MMW radiation.

The above authors concluded that the detailed cellular and molecular mechanisms mediating physiological responses to MMW exposure remain largely unknown.

These experimental studies demonstrate that cell membranes are highly sensitive to low-intensity MMW irradiation, and that non-thermal doses can induce structural rearrangements in membranes. There is thus reason to believe that biological membranes are uniquely sensitive “detectors” of radiation in living cells.

Some studies have found that low-intensity MMWs inhibit cell cycle progression (Le Drean et al., 2013).

At a special workshop of the BEMS symposium in 2017, Markov, based on his own biophysical experiments on the effect of MMWs, drew attention to the following features of the mechanisms of biological action:

1. the shallow penetration of MMWs into biological tissues causes preferential irradiation effects in the skin;
2. the effects of the double electric layer surrounding individual cells (transmembrane potential);
3. effects of charge distribution on the cell membrane;
4. changes in membrane permeability; and
5. the effect of MMWs on lipid-protein interactions in the cell membrane.

Dr Marko S. Markov, a Bulgarian scientist in the field of radiobiology and EMF therapy, has worked in the USA for 30 years

> *Research on the biological effects of millimeter waves should continue at the level of government organizations in order to find potential dangers of 5G technology* (Markov, 2018, 2019).

Long term MMW exposures have been shown to effect changes in the level of enzymes and proteins in the hippocampus, and double-strand DNA breaks. These effects were found by (Kesari & Behari, 2009) when male Wistar rats were irradiated with 50 GHz for 2 hours per day over 45 days at SAR levels of 0.8 W/kg.

MMWs have been shown to effect reproduction. Experimental studies were carried out using the classical model of drosophila. It was shown that MMW radiation (at a frequency of 37.5 GHz, with a sufficiently high radiation power of 250 mW) applied to virgin females of Drosophila melanogaster (vinegar flies, also known as "fruit flies") led to an increase in the yield of *male* imagos (adult flies) being produced from mature female gametes [eggs]. There was also a resultant increase in the death of individuals at the pupal stage. This effect depended on the genotype (Gorenskaya et al., 2017).

In summary, the results of MMW experimental studies on various microorganisms and cell cultures clearly indicate many definite biological effects on cells and cell membranes. When cells are irradiated with MMWs, both functional and structural changes are observed. Membranes can be instrumental in the effective perception and further manifestation of MMW action on cellular functional changes. For example, membrane permeability variations can change mitochondrial functioning and energy production in the cell, which over a long period of time leads to disease.

Mechanisms underlying the effects of MMWs

A number of theoretical models have been proposed to explain the features and main mechanisms of the biological action of MMWs (Frohlich, 1980; Golant, 1989). Radio-physical principles of the effect of extremely high frequency EMF on living organisms in the interests of medicine were reviewed by Raevsky in 1997.

Since 1992, Belyaev et al. has conducted a large series of studies to assess the risk of MMW exposures, and also to investigate the mechanism of MMW action at the cellular level (Belyaev 1992, 1993, 1994, 1996, 2000). Bioeffects *in vitro*, the effect on the state of the genome, and the effect of MMWs on chromatin conformation in rat thymocytes (an immune cell present in the thymus) were examined. Data was obtained on the dependence of EMF-induced changes in the conformation of E. coli chromatin on a number of genetic, physiological and physical features of the studied culture. Belyaev also speaks of resonant effects. Many papers by Belyaev observed a strong dependence of the MMW effects on frequency and polarization at non-thermal power densities.

Effects of MMWs on the nervous and sensory systems

A number of acute-exposure animal experiments have demonstrated high sensitivity of various elements of the nervous system to MMW irradiation (Akoev et al., 1991; Sazonov et al., 1995; Saulya & Kihai, 2003).

MMWs have been shown to affect skin sensitivity. Enin et al. (1991) found that EMR frequencies of 55.61 and 73 GHz reduce the tactile sensitivity of the skin of rats. Gerashchenko et al. (1991, 1997) investigated the dependence of the absolute threshold of skin sensitivity by applying the frequency of microwave radiation that can cause increased skin sensitivity. This external stimulus led to a higher level of vital activity.

Sazonov (1998) investigated the possible effect of MMWs on the peripheral nerve structures of laboratory animals (at 37-55 GHz, non-thermal intensity <10 mW/cm^2). This experiment indicated that MMWs can be perceived by biological receptors, which by their modality are not intended for the perception of this physical factor. MMW exposures can have an impact on the nervous structures not only directly, but also through the surrounding tissue. This is a significant departure from the usual "thermal effect" studies that investigate MMW biological impacts.

MMWs have been shown to affect the responsiveness of both the peripheral and central nervous systems. Research by Alekseev et al. (2010) showed that MMWs with a frequency of 42.25 GHz changed the electrical activity of the mouse calf nerve. The threshold of intensity at which there is an increase in spontaneous impulse activity of the calf muscle is quite high, at 160 mW /cm^2.

Experimental studies conducted on isolated nerve preparations (squid axon, frog sciatic nerve, etc.) demonstrated the possible effects to peripheral elements of the nervous system when directly exposed to MMWs (Akoev et al., 1991; Sazonov, 1995). In the research of Voropaev et al. (2004) changes were found in the amplitude of the EEG alpha rhythm, depending on the frequency of the MMW exposure.

Alekseev et al. (1987) investigated the effect of MMWs (61.22 and 75.0 GHz) on the spontaneous electrical activity of pacemaker neurons in the Mollusc Lymnaea stagnalis. The development of a dynamic reaction of inhibition of electrical activity of neurons was shown. The effects of microwaves were found not only in the terminal nerve endings, but also in nerve fibers.

Popov et al. (2001) concluded that MMWs are perceived by mast cells. According to Alekseev et al. (2010), the changes detected in the electrical characteristics of a nerve when exposed to MMWs may be a consequence of the action of mediators released during the degranulation of mast cells that are located around the nerve endings. These mediators reach the nerve receptors and excite them. Histamine release during mast cell degranulation may cause changes in the myogenic mechanisms of microcirculation vessels (Tribrat & Chuyan, 2010; Chuyan et al., 2011). Thus, substances released from mast cells can have a local effect as well as affecting other functions of the body.

The response of the nervous system to MMWs can also be assessed by studying changes in mammalian behavioral responses. For example, it was shown that millimeter waves are able to modify the conditioned reflex activity of rats (Khramova, 1989).

There are a number of studies indicating that complex mediated systemic reactions of body functions occur when skin is irradiated with MMWs. In the article "Modern ideas about the mechanisms of physiological action of millimeter waves (literature review)" Temuryants et al. (2012) proposed four stages of classical events that lead to the body's response to the stimulus of MMWs on the skin:

1. Primary reception;
2. Signal transmission to the central nervous system (CNS);
3. Analysis of the received CNS information; and
4. Proportional systemic response.

Experiments have shown that the neuroendocrine system of animals exhibits great sensitivity to MMWs. In the first place, for the hypothalamus and pituitary gland, only small exposures are required to elicit a reaction (Smorodchenko, 1998). Additionally, studies showed an increase in cortisol levels and testosterone in the blood, with a corresponding adaptation of thyroid hormones (Adaskevich, 1995; Lisenkova et al., 1995). For the medulla oblongata, there are modified levels of the monoamine component of the immune organs, the thymus and spleen (Smorodchenko, 1998).

A study of changes in pain sensitivity after MMW skin irradiation was conducted by Radzievsky et al. (1999) under double-blind experimental conditions. The skin in the lower third of the sternum was exposed to 42.25 GHz MMWs at 25 mW/cm^2 for 30 minutes, or it was subjected to sham exposure from a non-working MMW transmitter. The volunteers then made scaled judgements that indicated their pain sensitivity and tolerance to having their hand placed in an icy-cold bath. Responses after real exposures were compared with sham exposures. Overall, MMW exposure increased pain tolerance by 37.7%. These results suggest short term exposures to MMWs can change the responsiveness of the nervous system to painful stimuli.

In 2011, Chuyan, Tribrat and Ananchenko reported that the influence of MMWs on the maintenance of a healthy psychophysiological state depends on such factors as the age of the subjects and the properties of the nervous system; in particular, the strength of the nervous processes, the predominance of a sympathetic or parasympathetic link in vegetative nervous systems, temperament, and interhemispheric asymmetry.

The interested reader can obtain further information on the effects of MMWs on the nervous and sensory systems in other research publications (Le Drean et al., 2013; Frohlich, 1980; Gandhi, Lazzi & Furse 1996; Postow & Swicord, 1986; Temuryants et al., 2012; Torgomyan & Trchounian, 2013; Foster et al., 2016; Simko & Mattsson, 2019; Wu et al., 2015). However, the results described in these reviews have not been replicated in independent laboratories, so they cannot be considered as established biological effects.

Effects of modulated MMWs on the heart and circulatory system

The responsiveness of the heart to MMWs has been investigated closely in the Russian research, described in the review below. In particular, the effects of low frequency modulations have been shown to be significant, leading to concerns for heart health during the 5G rollout.

Chernyakov et al. (1989) were able to cause changes in the heart rate of frogs by irradiating distant skin areas with MMWs. From the point of view of classical physiology, it is important that the delay of these changes was about one minute. The authors suggest that a reflex mechanism of the action of MMWs was at work, possibly involving certain peripheral receptors. This data is consistent with more recent work.

It was further shown that the effects are frequency dependent. Certain frequencies in the 53-78 GHz range effectively altered the natural heart rate variability in anesthetized rats. Irradiation was applied to the upper thoracic vertebrae for 20 minutes at 10 mW/cm^2 or less. Frequencies of 55 and 73 GHz caused severe arrhythmia, and the coefficient of variation of the RR interval increased four to five times during ECG measurements. Exposure at 61 or 75 GHz had no effect, while other frequencies tested caused intermediate changes. A similar frequency-dependence was observed in additional experiments with three-hour exposures; however, about 25% of these experiments were interrupted due to the sudden death of the animals, which occurred after 2.5 hours of exposure at frequencies 51, 61 and 73 GHz.

Similar results were obtained in an experiment using an animal model of isolated frog hearts (Afrikanova & Grigoriev, 2005). In these experiments, irradiation occurred at 9.3 GHz EMF, at a low level of intensity. Since the size of the frog's heart is comparable to the radiation wavelength, the irradiation was performed under conditions approaching the maximum absorption of radiation energy by the object.

The RF signal was presented both in continuous mode and pulse modulated using a complex signal. The principle of time-varying frequency and associated modulations with a constant narrowing of the frequency set was applied. Frequency modulations were varied (i.e. drifted) from 1 to 100 Hz at a modulation depth of 30 and 100%. The pulse shape was rectangular, meander, PD of 0.016 mW/cm^2. The distance to the object was chosen so that its irradiation was uniform. A total of 180 frog hearts were used. The general scheme of experimental conditions is given in Table 1.

Observations were recorded during irradiation and following exposure for a further 24 hours. The heart rate was recorded every half-hour for six hours from the time the isolated hearts were prepared, during exposure, as well as through the day following the irradiation. Similarly, observations were also carried out in the controls (sham exposure) at the same time intervals. In assessing the response to the radiation exposures, it is important to note that the heart can continue to contract for two days in Ringer's (isotonic) solution.

Table 1: General characteristics of experimental conditions (Afrikanova & Grigoriev, 1996)

Experiment number	Number of animals used		Power Density mW/cm^2	The mode of generation of EMF and the exposure time in minutes			Total time of irradiation in minutes
	Number exposed	Number of controls		Constant	Pulse Frequency Hz	Time of each mode in minutes	
1	28	28	0.016	No	6-10	1	5
2	32	32	0.016	No	1-10	1	10
3	20	20	0.016	No	1-10, 20, 30,40, 50, 60, 70,80, 90,100	1	19
4	10	10	0.016	Yes	No	5	5

Morphological states of excitable heart tissue were investigated. Vital staining of atrial septal structures was performed with azine group (organic compounds) with neutral red (AC) dye. The method of *in vivo* staining made it possible to judge the viability of structures by the criterion of granulation, as well as the state of their permeability (by the degree and dynamics of staining). Another vital stain, methylene blue, was used to assess the state of cholinergic synapses on neurons of the sinoatrial (SA) node.

Control groups: The heart rate of intact unstained hearts slowed down by an average of 7% during 24 hours of observation; but there was no cardiac arrest (see Figure 5). The immersion of the isolated heart sample in dye solution alone for half an hour led to a change in its function: the number of contractions decreased by 30%, and 14% of the hearts stopped contracting. When the arrested hearts were stimulated by strong light or a mechanical stimulus to the pacemaker area (sinus venosus), the heartbeat was restored.

Upon termination of the heart-staining process the rate of contractions gradually increased to reach the initial level. By the end of the experiment, after 24 hours, the heart rate had only decreased by an average of 20%.

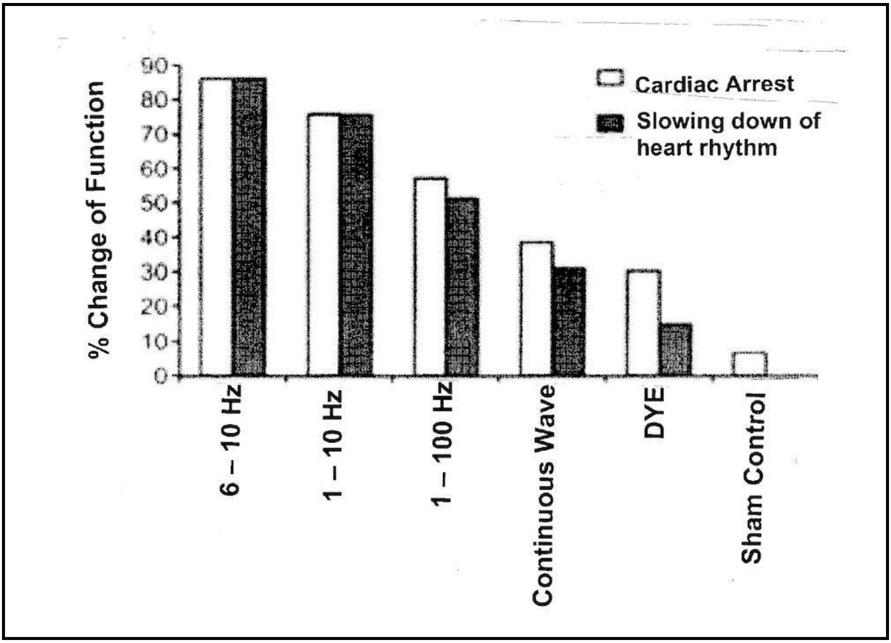

Figure 5: Heart rate variability and arrests in isolated frog hearts irradiated with RF in continuous mode (CM) and with (ELF) pulse modulation varying 1-100 Hz

Continuous RF exposure: The reaction of the hearts irradiated with continuous wave was insignificant and did not differ much from the dyed non-irradiated hearts.

Pulsed modulation exposure: When irradiated in the modulated EMF mode, a sharp decrease in the number of heart beats was observed, and the number of hearts that stopped beating also increased (Figure 5). The greatest effect was found when the frequency modulation change occurred in the range of 6-10 Hz and the exposure time was five minutes. Under these conditions of exposure, the rhythm slowed down, with subsequent cardiac arrest in 85% of the hearts (compared to only 38% for continuous mode). These effects were only partially reversible.

When the irradiated hearts were rinsed from the dye they resumed their contractions and increased their rate. However, during the next 2-3 hours, a sharp decrease in heart-rate and an increase in secondary cardiac arrests were noted in a large percentage of cases. In these cases, stimulating procedures led only to a short resumption of heart contractions. At 2-3 hours after exposure to modulated EMF, a violation of the granule formation process was observed in the neurons and muscle elements of the heart. A large number of neurons acquired angular shapes and the nucleus and cytoplasm had a diffuse color. In the muscle fibers, the number of dye granules was reduced, the cytoplasm was slightly tinted, and many muscle nuclei were also coloured intensely red. At the same time, the phenomena of gelatinization of synapses on the cells of the subthalamic nucleus and intensive tinting of Schwann cells in the zone of the axonal growth cone were noted. Such results may indicate a violation of the viability of these structures of the heart that were irradiated, i.e. the development of a process such as paranecrosis.

In summary, this series of experiments that examined frog hearts irradiated with RF-EMF pulse modulated signals in the frequency range from 1 to 100 Hz shows a significantly greater effect on heart function when compared to hearts irradiated with continuous (sinusoidal) unmodulated RF-EMF.

The correlation of bioeffects with the initial state of the body system and different RF-EMF modulations was studied earlier by Afrikanova and Grigoriev (1966). The isolated frog heart model was also used for this study. Isolated frog hearts were irradiated with EMF of 9.3 GHz, and a power density exposure of 0.016 mW/ cm^2 (1.6% of the ICNIRP public exposure limit).

In the initial state, according to the heart rate, the hearts were divided into 3 experimental groups (see Table 2):

1. 20-30 beats per 1 minute;
2. 31-40 beats per 1 minute; and
3. 41-50 beats per 1 minute.

In these experiments the pulse mode of EMF exposure was used. The frequency of the pulsed EMF exposure was determined in consideration of the initial heart rate of the isolated heart: 20-30, 31-40 and 41-50. Thus, the low frequency modulations were made in three modes (see Table 2):

1. 20, 22, 24 and 25 Hz;
2. 32, 34, 36 and 38 Hz; and
3. 40, 42, 44, 46 and 48 Hz.

Table 2: Changes in the heart-rate of isolated frog hearts depending on the modulation of the microwave frequency and the initial heart rate (emphasis added here shows the greatest change)

Experiment number	Number of hearts	Modulation Hz	Number of points (average by group) Initial frequency of the beating heart			Total number of points
			20-30	31-40	41-50	
I	23	20, 22, 24, 25, 28	**50**	**3**	**3**	**56**
II	28	30, 32, 34, 36, 38	11	12	9	32
III	22	40, 42, 44, 46, 48	9	1	16	26
IV	26	Continuous Mode	1	-	-	2
V	30	Sham exposure	-	-	-	0

The duration of each exposure was 1 minute. There was also a continuous (unmodulated) RF-EMF exposure (Group IV) and sham (no RF) exposure group (Group V). The magnitude of the changes was estimated using a ranking system (i.e., the greatest modification was given the highest rank, and the smallest modification was given the lowest rank of 1. The ranks were then averaged to give the points for each experimental condition (see Table 2).

The greatest changes occurred with EMF exposure in the 20-28 Hz modulation mode in the group of hearts with a frequency of 20-30 beats per minute. Thus, the authors found that a change in the physiological system occurred when the system was initially in synchronization with the frequencies that were modulating the 9.3 GHz EMF signal.

These results indicate the importance of considering modulations and not just carrier wave frequencies when setting safety guidelines. They also point to synchronisation effects of MMWs on the heart. These findings necessitate serious attention and further test studies.

Ananchenko & Chuyan (2011) found a definite effect of MMWs on regulation of tissue microcirculation using laser Doppler flowmetry. Subjects were 89 female student volunteers aged 18-23 years. According to the authors, when the skin is exposed to MMW irradiation, various components of tissue blood flow regulation play a major role in changing the micro-hemodynamics. The components that create these changes are the endothelium-dependent, myogenic endothelium-independent, and neurogenic blood flow components. These results are consistent with the work of Betzalel et al. (2018) who showed a correlation between ECG (electrocardiography) parameters and the sub-THz reflection coefficient of human skin.

It has been shown that a significant effect can be obtained by using modulated MMWs and purposefully influencing the systems of enzymatic reactions in the cell where the characteristic frequencies are close to the frequency modulation (Gapeev et al., 1994; Gapeyev et al., 1998, 2001). There is also information about the inhibitory biological effect of exposure to MMWs in the modulation mode (Gapeev & Chemeris, 2000). Narcolepsy (the falling-asleep effect) was registered in rats when exposed to MMWs (37 GHz; PD<0.3 mW/cm^2) modulated by delta brain rhythm frequencies.

Effects dependent on initial state of the system

Experimental data obtained at the subcellular, cellular and tissue levels indicate the dependence of the EHF (extremely high frequency) EMR effect on the initial level of activity of a biological object (Pakhomov et al., 1998; Geletyuk et al., 1995; Rojavin et al., 1997).

According to Pakhomov et al. (1998), individuals or groups of the population that are usually considered homogeneous can react to MMWs in quite different or even opposite ways. For example, in animal experiments by Temuryants & Chuyan (1992) and Temuryants et al. (1993), the authors separated rats in different animal enclosures based on their levels of activity before MMW exposure. The reactions of animals with low, medium and high levels of activity differed greatly in their response to MMWs. The variation in the nature of the microcirculation under the influence of MMWs was dependent on the initial state of the animal (Ananchenko & Chuyan, 2011). Thus, ignoring individual differences in the population can mask possible bioeffects of MMWs, or lead to erroneous conclusions.

The initial state of the biological system can affect the bioeffects of MMW exposures.

Biological resonance effects

From the early 1970s the Institute of Cell Biophysics (a unique science center within the Russian Academy of Sciences, now known as the "Pushchino Scientific Centre of Biological Research") conducted intensive studies of the *mechanisms* of the biological effects of MMWs. In particular, the research identified the MMW parameters that produce bio-resonance effects (i.e. synchronisation of oscillations between the biological object and the exposure signal). This research was conducted by Gapeev, Chemeris, Alekseev and Fesenko.

Mechanisms of the biological action of low-intensity MMWs at the cellular level were examined theoretically and experimentally (Gapeev, Safronova, Chemeris et al., 1996; Gapeyev, Safronova, Chemeris et al., 1997; Gapeyev, Yakushina, Chemeris et al., 1998). In these studies, the designers used a *grooved* antenna. The grooved antenna, in contrast to the dielectric and horn antenna, provides a uniform spatial distribution of the specific absorbed power in the frequency range used and allows for broadband matching (of the transmitted EMF signal) with the target object, both in the near and far zones of the emitter. For the first time, it was shown that the response of the immune system cells (mouse neutrophils) to low-intensity MMWs (1-150 μW/cm^2) has a *resonance-like* character, depending on both the carrier and modulating radiation frequencies (Gapeev et al., 1996).

Ground-breaking data was obtained showing that the occurrence of MMW effects was dependent on the induction of a constant magnetic field comparable in magnitude to the geomagnetic field of the earth (Gapeev. et. al., 1999). Based on these experimental results, and using the methods of stability theory and the theory of deterministic chaotic oscillations, the changes in calcium-dependent processes of intracellular signalling under the action of low-intensity modulated MMWs were analyzed (Gapeev & Chemeris, 2000; Gapeev, Sokolov & Chemeris, 2001).

The discovery of the bio-resonance effect meant that for the first time, it was possible to explain the findings from various areas of research that had pointed to the dependence of the biological effect of EMFs on several factors: the functional state of the biological object; the presence of amplitude-frequency "windows" in the system's response to the impact; the threshold nature of the effect; and the role of white noise exposure as a control signal. It was shown that the *form* of the electromagnetic signal acting on the system was of prime importance for the qualitative and quantitative characteristics of the effect. This finding is fundamental with a view to potentially controlling the functions of various types of cells by exposing them to an external electromagnetic field with specially selected parameters.

Immunity and MMWs

The effect of low-intensity MMWs on various parts of the immune system of laboratory animals was studied. It was shown that in animals exposed to whole body irradiation, MMWs did not affect the humoral immune response (i.e., the antibody response, as estimated by the number of antibody-forming cells in the spleen and the titers of hemagglutination antibodies). However, MMWs reduced the severity of the cellular immune response in the delayed-type hypersensitivity (DTH/type IV) reaction (Lushnikov et al., 2001; Lushnikov et al., 2003).

Lushnikov et al. (2001) showed experimentally that exposures to low-intensity MMWs can affect the immune response. Healthy NMRI mice were used to examine the effect of low-intensity whole body MMW irradiation (42.0 GHz, 150μW/cm^2) on indicators of humoral immune response to thymus-dependent antigens. Animals were irradiated in the far zone of the antenna for 20 minutes in different modes: once, daily for five days, and daily for 20 days before immunization with sheep red blood cells. After immunization, they were then irradiated daily for five days during the development of the immune response. The intensity of the humoral immune response was assessed on the fifth day after immunization via the number of antibody-forming cells of the spleen and the titers of hemagglutinating antibodies. The spleen mass, thymus, spleen and red bone marrow cellularity were determined.

From our point of view, an extremely important conclusion was formulated concerning the cumulative nature of whole-organism-response to MMWs, that is, ***the presence in the body of mechanisms for the accumulation of bioeffects and recognition of the stimulus of radiation exposure.***

There were no significant differences between these indicators after single-day and five-day irradiations in the formation of the immune response. After an exposure series of 20 days, however, thymus cellularity significantly decreased by 17.5%, and spleen cellularity by 14.5%. These authors believe that the results obtained serve as evidence that repeated exposure of healthy animals to low-intensity MMWs can affect the processes of immunogenesis.

Lushnikov et al., (2003) used a delayed-type hypersensitivity reaction (type IV) to assess the effect of MMWs on cell-mediated immunity. To stimulate the type IV hypersensitivity reaction, mice were sensitized by the introduction of 1x10^7 sheep red blood cells. Animals of the experimental group were then subjected to whole-body irradiation by MMWs (42.0 GHz, 100 μW/cm^2) for five consecutive days (for 20 minutes per day) after the sensitizing injection and before the allowable injection. It was thus shown that the application of MMWs almost entirely suppresses non-specific inflammation caused by subcutaneous injection of red blood cells, and reduces the severity of immune inflammation.

It was found that non-specific immune reactions are highly sensitive to the action of low-intensity MMWs (Kolomytseva et al., 2002).

The irradiation of intact mice with MMWs resulted in a significant decrease in the number of active phagocytes (percentage of phagocytosis) in the peripheral blood. An original discovery was made through the electrophoresis of individual cells in agarose gel (DNA comet assay method): exposure to low-intensity MMWs led to a change in the spatial organization of chromatin cells of immunogenic organs (thymus and spleen) of animals (Gapeev, et al., 2003).

Using in vivo studies of acute non-specific inflammation, Lushnikov et al., (2005) demonstrated for the first time that low-intensity MMWs (42.0 GHz, 100µW/cm^2, 20 min) can have a pronounced anti-inflammatory effect. It was found that the kinetic parameters and magnitude of the anti-inflammatory effect of MMWs are similar to those of a single therapeutic dose of the nonsteroidal anti-inflammatory drug Diclofenac (Voltaren). Diclofenac is a drug that reduces inflammation and pain. The combination of both diclofenac sodium and MMWs effected a partial additive effect by reducing exudation and hyperaemia at the site of inflammation.

The results of the above comparative analysis of experiments suggest that the anti-inflammatory effect of low-intensity MMWs occurs by inhibiting the key enzyme of the inflammatory reaction, cyclooxygenase, which is followed by a decrease in prostaglandin synthesis.

It was shown that cellular mechanisms are responsible for the anti-inflammatory action of MMWs. This is associated with changes in the functional activity of phagocytic cells. The inflammatory bioeffect was due to a decrease in phagocytic activity and the production of reactive oxygen species. These results allowed the authors to propose a "histamine" hypothesis based on the biological action of MMWs at the level of the whole organism (Gapeev et al., 2006).

The above research explains the rationale for the effective use of MMWs in the treatment of diseases where the pathogenesis includes pronounced inflammatory processes.

To explore the anti-inflammatory and anti-tumor effects of MMWs, a wide range of radiation parameters were investigated. These parameters included differing intensities, carrier and modulating frequencies, and exposure durations. As a result of these investigations, the optimal modes of exposure to produce pronounced biological effects such as anti-inflammatory, anti-tumor, and genoprotective effects were determined (Gapeyev, 2011; Gapeyev & Lukyanova, 2015; Gapeyev, Aripovsky & Kulagina, 2015; Gapeyev, Aripovsky & Kulagina, 2019). Low frequency pulsing of 0.07-0.1, 0.5-2 and 20-30 Hz were found to have especially pronounced effects (Gapeyev & Mikhailik et al., 2008).

The possibility of a synergistic effect of modulated electromagnetic radiation was confirmed when using a special combination of carrier and modulating frequencies (Gapeyev, Mikhailik & Chemeris, 2008; 2009.

The pronounced response of chromatin in lymphocytes is one of the major contributing factors in creating the synergistic effects from MMW. Chromatin in lymphoid cells is pivotal in limiting cell damage from radiation in the inflammatory process. The activation of T cell immunity is seen in the rapid mobilization of mature T lymphocytes from the spleen and thymus of irradiated animals, and in the rapid rise in the number of omega-3 and omega-6 polyunsaturated fatty acids in the thymus of irradiated animals. This leads to the creation of a specific cytokine profile that causes the anti-inflammatory effect of MMWs (Gapeev, Sirota, Kudryavtsev & Chemeris, 2010).

MMW effects are systemic

It has been shown by Popov et al., (2001) that local exposure to low-intensity MMWs leads to degranulation of mast cells of the dermis. The authors suggested that the reaction of mast cells of the skin may be an important amplifying mechanism in the chain of events leading to a systemic bodily reaction to the stimulus of low-intensity MMWs through the participation of the nervous, endocrine and immune systems.

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The results from Lushnikov, Gapeev, Chemeris et al. (2002) demonstrate that MMWs produce a *systemic effect* on the whole body which is directed through the regulatory systems responsible for maintaining homeostasis.

The results obtained here indicate that the main mechanism through which low-intensity MMWs act, involves the modification of the immune status of the body as a result of a systemic reaction to the radiation exposure. Through the signalling system described above, the body can be directed (stimulated) to respond to electromagnetic radiation using a specific combination of radiation parameters.

Thus, it is necessary to study both the primary reception of MMW exposure by the biological system, and the subsequent response at the immune system level. The effect of MMW exposures on the skin was quite clear. It is thus confirmed that the skin plays an instrumental role in the mechanisms of biological action of EMR (Rodshtat, 1985; Ilina & Betsky, 1989; Popov et al., 2001; Alekseev & Ziskin, 2009).

Therefore, it is necessary to study not only the primary reception of MMWs, but also the subsequent perception and response at the level of physiological reactions of the whole organism. EMR is detected within complex biological systems and this is distinctively manifested at the level of the whole organism (Presman, 1968; Plekhanov 1990; Lushnikov, Gapeev et al., 2001).

Based on the results of the work of specialists at the Institute of Cell Biophysics (now known as the "Pushchino Scientific Centre of Biological Research") within the Russian Academy of Sciences, and other researchers in Russia and overseas, the following conclusion can be stated:

> *The immune system is critical to biological and human health. The immune system is affected by low-intensity MMW radiation. This finding is particularly pertinent during the Covid-19 pandemic, due to increased demands on the immune system.*

Problems with experimental design and reporting

Belyaev et al., (2000) drew attention to the fact that there are a significant number of studies showing biological effects from MMW exposures at non-thermal intensities. However, some replication studies have reported low reproducibility of these effects. This lack of reproducibility is then used by ICNIRP to deny risks. According to the authors, one possible explanation may be the dependence of the MMW effects on parameters that were not controlled during replication.

Other factors can also influence experimental outcomes, such as the genotype of cell strains, the growth stage of bacterial cultures, and the time between exposure to microwaves and the observation of the effect. These considerations reiterate the extreme importance of recording the exact details of methods used when conducting studies of MMWs of non-thermal intensities.

There are numerous examples in the literature where a single exposure to modulated RF-EMF signals results in an initial appearance of DNA damage, but hours later the damage disappears. Here, DNA repair mechanisms have been activated and repaired the damage. If the experiment is halted at this point, the conclusion would be of a null or protective effect. However, if exposures continue over days, weeks or months, then biological repair systems are overwhelmed and DNA damage is once again observed. The conclusion is then of a significant damaging effect of exposure on DNA. Thus, duration of exposure plays a crucial role in outcomes, Unfortunately the majority of studies have been short-term only.

We consider it appropriate to pay attention to a number of other factors that can significantly affect the final radiobiological effect. Many experiments reach their conclusions without considering the modulation, pulse mode, and pulsation in the carrier signal (Grigoriev, 1996; Leach, Weller & Redmayne 2018). Furthermore, the vast majority of experimenters do not consider the synergistic side-effects of other toxic stimuli together with MMWs (Kostoff, Heru, Ashner et al., 2020).

Author's assessment of potential health effects from 5G

The impact of low-intensity MMWs on living systems is found in many experimental animal studies. Biological effects are observed in systems of varying degrees of complexity, from the microbial and cellular levels, to the level of the whole organism.

From our evaluation of the results of preliminary studies on the possible impacts on the health of the population of the 5G MMW-exposures alone (i.e., excluding other anthropogenic RF-spectrum exposure effects, or combined effects), we consider it reasonable to expect the following adverse effects: impacts on normal functioning in the critical organs of the skin and eyes; mediated systemic reactions in the body as a whole; and, most notably, impacts to the nervous and immune systems.

> *When considering short-term exposures to low-intensity MMWs, two organs are of critical importance. These are the skin and the eyes.*

It is clear that when the population is exposed to MMWs, the absorbed dose(s) recommended by the FCC and ICNIRP may be exceeded. Since there is insufficient scientific information on possible adverse bioeffects from millimeter waves, it is not currently possible to determine scientifically-based public health standards and protective national policies for 5G exposures.

The potential impact of MMWs on the biosphere is a valid and grave concern. As a result of the technological developments that are changing our former (more traditional) way of life, and, despite the gaps in our scientific knowledge, it is necessary for us to try to foresee the human health consequences that may occur in diverse population groups.

Reaction of countries to the introduction of 5G technology

Our above-stated conclusions and concerns regarding the potential public health risk from the adoption of the new 5G technological standard is reflected in reactions around the world. 5G deployment is contested in a number of countries and territories:

- ❖ From 2020, Swiss municipalities have insisted that proof of the safety of 5G should be apparent before installation permits for the introduction of the technology can be approved ("Why the Swiss are rebelling against 5G rollout", September 2019).
- ❖ Following growing concerns about the public health implications of the 5G network, the Nigerian government refused to approve the deployment of the 5G network in the country ("Nigerian Government Denies Issuing Licence For 5G Network Deployment", Sahara Reporters, April 2020).
- ❖ Slovenia halted the introduction of 5G technology pending the results of studies on public health and safety ("Slovenia halts 5G to investigate health and safety", Environmental Health Trust, March 18 2020).
- ❖ More than 140 Italian cities decided to stop deploying the 5G standard ("International Actions To Halt And Delay 5G", Environmental Health Trust, April 2019).
- ❖ The Belgian environment minister said that their citizens "will not be guinea pigs whose health can be sold at a profit" ("Radiation concerns halt Brussels 5G development, for now", The Brussels Times, April 2019).
- ❖ The United Kingdom (UK) requires an urgent health and safety assessment on 5G ("International Actions To Halt And Delay 5g", Environmental Health Trust, April 2019).
- ❖ In Australia and New Zealand, concerns have been raised over the lack of research on the possible adverse health effects of 5G technology (Bandara et al., 2020).

A group of scientists from New Zealand and Australia published a discussion paper in July 2020 entitled "5G Wireless Network Deployment and Health Risks: A Time for a medical discussion in Australia and New Zealand" (Bandara et al., 2020). The authors of this paper expressed their concern as follows:

> *An urgent medical investigation into the safety of existing wireless signals (WiFi, 3G, 4G) and the new 5G is required…*
> *The lack of clinicians and biomedical experts within the ARPANSA expert panel for their health risk assessment, along with their seriously questionable conclusions appear to have mislead* [sic] *the Australian medical system…*
> *Unsubstantiated claims of safety on a public health matter are risky. In this case, it involves population wide exposure to a novel man-made form of microwave radiation that can put people's health and quality of life at serious risk…* (Bandara et al., 2020 p 31.)

Scientists in Australia have drawn attention to the fact that unsuitably qualified (or questionably-appropriate) "specialists" are tasked with handling the safety of RF exposures for the public. For example, an examination of brain tumor rates, conducted by these "experts" from ARPANSA and ACEBR (Australian Centre for Electromagnetic Bioeffects Research), concluded that there can be no link between mobile phone use and brain cancer (Karipidis et al., 2018). This study was met with great skepticism as it did not look at the under 20 and over 60's age groups. Nonetheless, it is being used by ARPANSA to reassure the public that mobile phone use is entirely safe (ARPANSA website, "New Australian study finds no link between mobile phone use and brain cancers", 2018).

In contrast, Bandara et al. (2020) request adequate research before deployment:

> *The plan to deploy 30,000 satellites in space and millions of 5G transmitters on Earth without any formal health or environmental assessments is both reckless and negligent. We appeal to the medical community in Australia-New Zealand to actively engage with this important topic in order to protect public health.* (Bandara et al., 2020 p 32.)

Minor violations of certain health parameters can translate into severe damage for public health if large numbers of people experience impaired body functions. In this case, the entire population can be affected, and this can result in devastating consequences both for the general health of nations and, subsequently, for the economy.

To be truly progressive we need to promote uniquely innovative methods to further technological evolution, but in ways that do not harm biological systems. These technologies can only be implemented after bona fide objective scientific research.

Currently, wired alternatives represent a safer, more sustainable and thus ultimately more affordable way forward.

PHIRE (the Physicians' Health Initiative for Radiation and Environment) is an independent UK-based association of doctors and medical researchers. They collect and disseminate research in the field of EMF health effects, as well as conducting their own studies. Last year they issued their "2020 Consensus Statement of UK and International Medical and Scientific Experts and Practitioners on Health Effects of Non-Ionising Radiation (NIR)".

Here is an extract from this statement:

> *We the undersigned state that the above 'Urgent Action Points' must be addressed immediately by the UK Government and other governments internationally, in order to prevent avoidable human injury, disease, deaths and potentially irreversible environmental damage. People must be allowed to retain the right not to be exposed against their will. Where prevention of harm may have already failed we also request clear communication to the public regarding who is accountable and liable for health damages. We request a response from Public Health England and Her Majesty's Government to clarify accountability and the measures which will be taken to address the above 'Urgent Action Points' within 28 days of receipt of this communication* (PHIRE, 2020).

This appeal was signed by more than 300 doctors and scientists, including the author of this book, Professor Yuri Grigoriev.

Figure 6: International consensus statement

The appeal was approved by the following medical associations and scientific forums: the Physicians' Health Initiative for Radiation and Environment (PHIRE); the British Society for Ecological Medicine (BSEM); the Alborada Foundation (Spain); the American Academy of Environmental Medicine (AAEM); the Australasian College of Nutritional and Environmental Medicine (ACNEM); the European Academy for Environmental Medicine (EUROPAEM); the Italian International Society of Doctors for the Environment (ISDE Italia); National Association of Environmental Medicine (NAEM, USA).

The Australian parliament held an inquiry into 5G in 2019-2020. The terms of reference, however, did not include the potential impact on health which was largely ignored, citing the ARPANSA or ICNIRP standard as being sufficient to protect health. There were 538 submissions, and over 80% of these were concerns about potential health effects which were not addressed. On average, each witness group that was a proponent *for* 5G was given around 45 minutes hearing time with the committee, while each witness group *against* 5G (including ORSAA) received an average of only 12.5 minutes.

ORSAA has since expressed their concern regarding the lack of democratic fairness within the inquiry process. In their submission ORSAA implored the government to immediately halt 5G deployment in consideration of the potentially serious risk to public and planetary health, and to find the political will to prudently address the scientific evidence of potential health consequences (ORSAA, "Submission to the Australian Federal Parliament's House of Representatives Standing Committee on Communications and the Arts: Inquiry into 5G mobile telephony", 2019).

The failure to address the potential health impacts of 5G in this inquiry is an example of how real information about the potential health impacts from the many various sources of EMF exposures (3G, 4G, and 5G) are being concealed from the public.

Outside of Russia, the current situation has already been referred to as "the biggest experiment in the history of the world".

Irradiation of the human population by MMWs without the appropriate precautionary standards is clearly immoral—in the same way as conducting or observing an experiment would be, when it has the possibility of developing pathological processes;

e.g., according to the notion: “Wait and see… *then* we will be able to establish proper standards” (Grigoriev, 2018; Grigoriev, 2018; Grigoriev, 2018). Of course, by then, it will be too late!

Part Two: An Integrated Summary of Public Health Risk from Radiofrequency Electromagnetic Field Exposures

How do we assess the total risk to human health from the impact of planet-wide RF-EMF exposures?

To accomplish this task, we need to take into consideration the simultaneous use of 3G, 4G and 5G communication technologies. In Part One, we identified human health risks for 5G cellular technologies. In Part Two, we will now tabulate pre-existing research results of the specific bioeffects from 3G and 4G technologies. We will then be able to integrate the current state of scientific knowledge from both of these (old and new) risk sets, to include all three technological standards—3G, 4G and 5G. Finally, we will formulate a complete hazard assessment of the planet-wide RF-EMF exposures, and present our public health recommendations.

We now turn the reader's attention to the 3G and 4G cellular communication standards, which are the major sources of RF-EMF exposures today. The technologies associated with these include (1) base stations (BS) together with Wi-Fi access points (AP), and (2) user (or subscriber) terminals such as mobile phones, laptop computers, and other wireless devices. Each of these two sources of exposure to the population varies significantly with regard to the area of the body that is irradiated, and also with the intensity and time period of the exposure. Base stations and Wi-Fi access points (APs) are sources of involuntary, whole-body, long-term (chronic) irradiation, while the use of mobile phones and devices creates voluntary, local, and more intense short-term exposures to the critical organs. The possible permutations of these various exposure factors should naturally be included in exposure assessments so that truly appropriate safety standards can be created.

Both base stations and Wi-Fi APs produce RF-EMF exposures for the entire human body, known as whole body or far-field irradiation. They are characterized by low and variable intensities that fluctuate with power and data stream usage, as well as intermittent beacon pulse exposures. There is an interplay between such far field exposures and those from devices; i.e., when the signal coming from a base station is weak, a mobile device will increase its power (or "power up"). Although the irradiation from mobile phones is localized, it created a higher intensity of exposure, for example, to the brain or the inner ear, or to the thyroid gland. These are known as near-field exposures.

While the exposure from cell phone base stations is 24 hours per day, seven days a week (and is continually growing as the number of users increases), the exposure from user terminals like Wi-Fi-connected devices and mobile phones can be periodic and short-term (but these also continue to grow over time as we use them more frequently).

It is important to consider both the time parameters of using devices (length of time they are used), and the specific conditions of their use, for example, up against the ear, or hands-free. From a radiobiological point of view, there may also be different combinations of accumulated bioeffects, depending on the nature of the signal itself; for example, the modulation and/or some other physical factors of the external environment. It is unacceptable to assess the health risks from mobile communications by excluding the combination of these pertinent factors.

The two main kinds of RF-EMF sources, base stations (including Wi-Fi APs) and wireless devices (such as mobile phones) are generally characterized as being far-field and near-field exposures respectively. As such, they are given separate and individualized consideration in the sections below.

Characteristics of our current electromagnetic environment

Far-field exposures: base stations and Wi-Fi access points

There is a massive and ongoing increase in anthropogenic background EMR levels, in conformations that do not naturally occur on planet Earth. While the EMR itself cannot be seen by the naked eye, the infrastructure producing the radiation is clearly manifested in our human environmental landscape in the form of base stations.

Indeed, today there is a whole set of new RF-EMF sources, for example, the base stations that irradiate humans 24-7, and which will result in lifelong RF-EMF irradiation of the whole body. Consequently, there is a blanket irradiation of entire population groups by individual RF-EMF carrier frequencies, as well as simultaneous irradiations by different sets of frequencies with various modulations. The resultant complex exposure pattern is driven by the utilization of the nearby base station which at any time can be servicing a number of mobile phone users connecting to multiple providers.

As explained in Part One, the 5G technology introduces a new concept in mobile telephony, Massive MIMO (Multiple In Multiple Out). This will use many different antennas to cover a single antenna sector. The technique offers advantages in that there is a greater capacity per user which equates to "faster" speed (via spatial multiplexing), and the signal quality is optimized in locations that are difficult to cover (spatial diversity). However, 5G adds to the complexity of the exposure pattern irradiating humans 24-7.

The engineering design of cellular communications is characterized by the division of geographical territories into zones (or cells). These zones usually vary in radius from 0.5 km to 40 km, depending on the population and the geographic features. The radiation from base stations is isotropic, radiating in all directions. There are now more than 500 thousand base stations in Russia. Base station antennas in Russia are required to be installed at a height of 15 to 100 m from the ground. This also applies to antennas installed on existing buildings. Antennas are placed on top of various buildings and structures such as chimneys, and on specially constructed masts. The power output (or radiation power density) at ground level from a particular base station is dependent on the time of day and the number of users connected through the antennas. The non-ionising radiation (NIR) power density levels at ground level depend on the demand for that particular base station.

The RF-EMF emission measurements of 347 cellular base stations were recorded in a study supervised by Professor Grigoriev. The range of power density measured in places accessible to the general public ranged from 0.17 to 471 $\mu W/cm^2$ (Yu. G. Grigoriev & Grigoriev, 2013; Yu. G. Grigoriev, Grigoriev, Ivanov, Lyaginskaya, Merkulov, Stepanov, et al., 2010). However, the maximum allowable power density (PD) in Russia is 10 $\mu W/cm^2$. The highest values were found on the roof of the buildings where the base station antennas were placed. Values exceeding the maximum allowable PD were also found within building premises, located less than 100 m from the antenna and along the azimuth (horizontal path) of the antenna's main projection. For residential developments, at a height of two meters from the ground, no excess power density was recorded at any of the measurement points. Today however, in violation of safety regulations, and, as a result of the relaxation of standards by the radiation protection agencies of various countries, base stations are far closer. They are installed within tens of meters of residential buildings, only two to three floors up from ground level, adjacent to the windows of residential premises along the azimuth of the projection of the main beam (see Figure 7).

Figure 7: A base station located a short distance from the windows of an apartment

Base stations induce an intricate pattern of time-varying, modulated and multi-frequency radiation exposures of a relatively low intensity. However, exposures from the emitted signals contain localized intensities that sometimes exceed the maximum allowable RF-EMF power density limits (ICNIRP 1000 μW/cm^2, Russia 10 μW/cm^2) and that approach levels that cause thermal effects. While the *average* intensity values within residential areas do not exceed the ICNIRP limit (and different countries have varying limits), they can still reach several hundred μW/cm^2.

Wi-Fi is an additional source of far-field RF-EMF exposures with frequencies of 2.4 GHz, and/or 5 GHz. For technical reasons, the range (or coverage) for Wi-Fi is restricted. Access points are provided for users and, importantly, the PD from these is typically ten times lower than the radiation from base stations. (It must be remembered, though, that the PD exposure for a user will also depend on their distance from the access point, since the inverse square law applies to both Wi-Fi and base stations). In our opinion, the potential hazard from Wi-Fi radiation exposure in the human environment should be considered in combination with EMFs of other frequencies and different modulations.

Wi-Fi can be seen as both a far-field and a near-field exposure, depending on factors such as the user's distance from the radiating source and the Wi-Fi frequency used. In this regard, it is also important to consider the details of *how* the user actually uses a device: its distance and location from the body, for example, on a user's lap (Markov & Grigoriev, 2013).

Some of the health concerns, where evidence for potentially serious pathologies from Wi-Fi radiation exposures has been identified include oxidative stress, sperm and DNA damage, neuropsychiatric effects, cell damage, apoptosis, and endocrine changes (Avendano, Mata, Sarmiento, & Doncel, 2012; Pall, 2018).

The artificial wireless signals produced by Wi-Fi access points and base stations are complex wave-forms with low-frequency modulations impressed on the high -frequency carrier wave, which can lead to adverse bioeffects. Experiments on rabbits in our laboratory have shown that the combination and interaction of complex exposures (several RF-EMF carriers with various frequencies of modulation and at a low intensity) resulted in the development of epilepsy (Yu. G. Grigoriev & Grigoriev, 2013; Yu. G. Grigoriev & Sidorenko, 2010).

Near-field exposures: mobile phones and other devices

Mobile phones and modern smartphones and tablets are powerful radiation-emitting devices. Although the type of radiation they emit is "non-ionizing", the devices should be treated with the same caution as low power ionizing radiation equipment. However, they are being used in an uncontrolled manner, without awareness that they are a significant source of EMF exposures and a potential health risk. Since these devices are publicly available, they are accessible to all population subsets, including children.

When a mobile phone is held up against the head for use, there is local irradiation of the brain. The vestibular and inner ear apparatus, including the auditory receptors, are in the direct path of the radiation (Yu. G. Grigoriev, 1997; Yu. G. Grigoriev, 2001). There is also intensive irradiation of the thyroid gland (Yu. G. Grigoriev et al., 2020). It is quite common for people to make frivolous and unnecessary use of their mobile phones, and to have a lack of awareness of the length of time they spend on their phone conversations.

When a wireless laptop is being used on a lap, the user's testicles are directly impacted by EMF. We must also pay attention to the irradiation of the intestine, which produces a number of neurotransmitters important for the normal functioning of the body.

During pregnancy and a baby's early years, there are many possible different sources of RF-EMF exposures to different parts of the body (see Figure 8). For example, an expectant mother might carry a cell phone against the pelvis (Figure 8a), talk on a cell phone for an extended period of time, or use a wireless-enabled laptop, tablet or smartphone (Figure 8b), or sometimes use a cell phone for "prenatal music therapy" (Figure 8c). In the first days and months after birth, the child can then be periodically exposed to EMFs. This occurs when parents use their mobile phones. Very often, this is while they are feeding the child.

In addition, if a baby is born prematurely, then the child is exposed to electromagnetic radiation while in the incubator. It is also quite common in the very first years of life for parents to introduce their children to a smartphone for entertainment purposes, so the child then perceives it as being just another toy (Figure 8d).

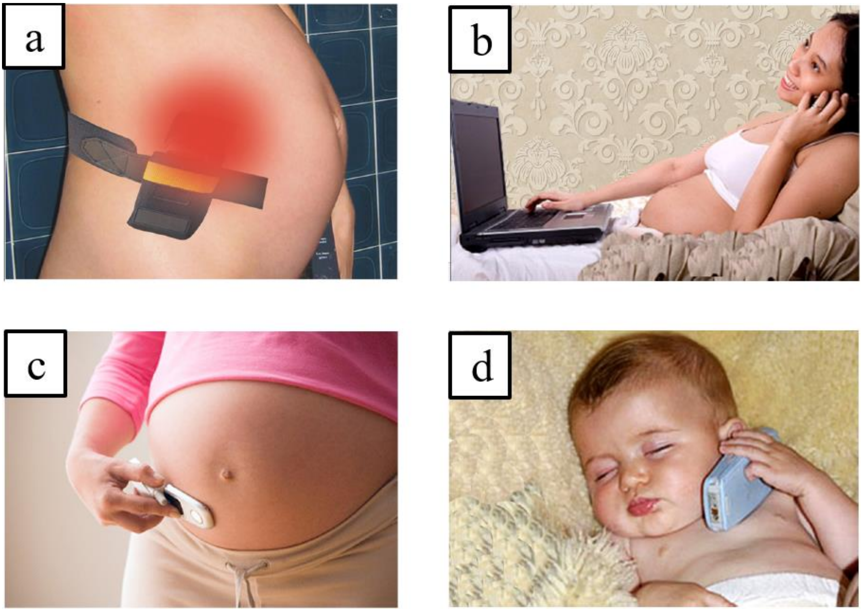

Figure 8: Near-field RF-EMF exposures in the child's early developmental stages, from prenatal to early childhood

We now turn the reader's attention to the biological and health effects that have been associated with 3G and 4G cellular communication technologies, such as base stations, Wi-Fi modems, smartphones and laptops, which are still the major sources of RF-EMF exposures today. In particular, children are constantly exposed to signals from these sources, and are likely to be exposed for decades to come.

Critical somatic organs and systems: The vulnerable brain, auditory and vestibular systems

The brain

For the first time ever in the history of civilization, the brain is now a critically vulnerable organ. It has not previously been exposed to RF-EMF radiation.

A mobile phone exposes the brain to different frequencies which can have various impacts. It is difficult to predict the amount of exposure one might have, either on a daily basis, or over a lifetime. Total exposure depends on both the specific device used, and the habits of the user. It is also relevant that mobile phone exposure is a near-field exposure which is typically unpredictable, and comprising wave properties that are hard to pinpoint. It is therefore difficult to predict the interaction of the electromagnetic fields from phones with tissue and bodily structures such as the inner ear. As a result, the effects of mobile phone exposure to the brain, in our opinion, can only be partially predicted. The forecast depends on many circumstances and, above all, on the choices of the users themselves.

Vital structures of the brain (see Figure 9), are directly exposed to RF-EMF radiation when a mobile phone is used against the head.

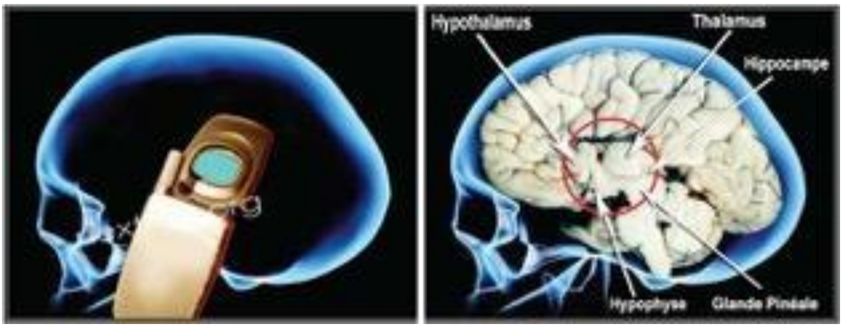

Figure 9: Irradiation of vital brain structures by RF-EMFs from mobile phones

The distribution of absorbed RF dose in the brain is entirely dependent on the age of the user (Gandhi, Lazzi, & Furse, 1996; see Figure 10).

The absorbed dose of RF-EMFs in the brain of children aged 5-10 years is up to two times greater than in adults. This fact gives weighty credence to our judgement that the brain and the nerve structures are critically vulnerable. Moreover, it indicates that when assessing the risk of mobile phones for the population, there *must* be a tailored approach to protecting children since their exposure, and that consequent *risk* from exposure to mobile phones is greater.

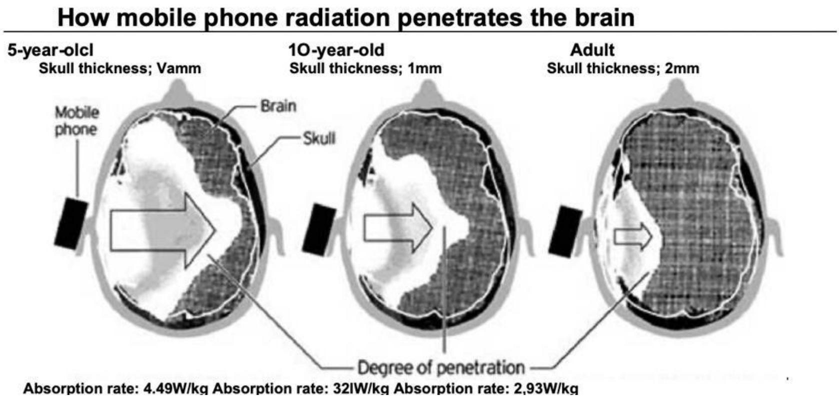

Figure 10: Distribution of absorbed dose in the brain in children aged 5 and 10 years and in adult mobile phone users (Gandhi et al., 1996).

The auditory and vestibular systems

In addition to the brain, the mobile phone also directly irradiates the auditory and vestibular systems of the inner ear, including the otolith organs and associated sensory pathways (Yu. G. Grigoriev, 2006). In the inner ear, the cochlea system is dedicated to the sense of hearing, while the vestibular system is responsible for maintaining a sense of balance and spatial orientation. Figure 11 shows the placement of these systems within the auditory system.

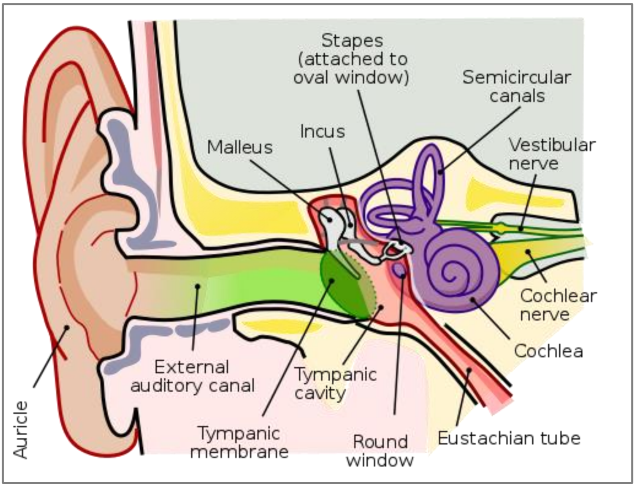

Figure 11: The position of the inner ear within the auditory system and its associated innervation. This work by Chittka and Brockmann is licensed under a Creative Commons Licence 2.5.

The inner ear contains hair-like receptors that, in response to fluctuations in the endolymph and basilar membrane (within the cochlea), send electrical impulses along nearby nerves to the brain.

The vestibular balance system comprises two components: the otolith organs and the semicircular canals. The two otolith organs, the utricle and saccule, contain a viscous fluid and small stones that assist sensory hair cells (mechanoreceptors) to detect linear acceleration, gravitational forces, and tilting movements. The three semicircular canals arise from the utricle and are filled with a fluid (endolymph) which is used to detect rotational acceleration. Both components of the vestibular system relay electrical impulses to the brain.

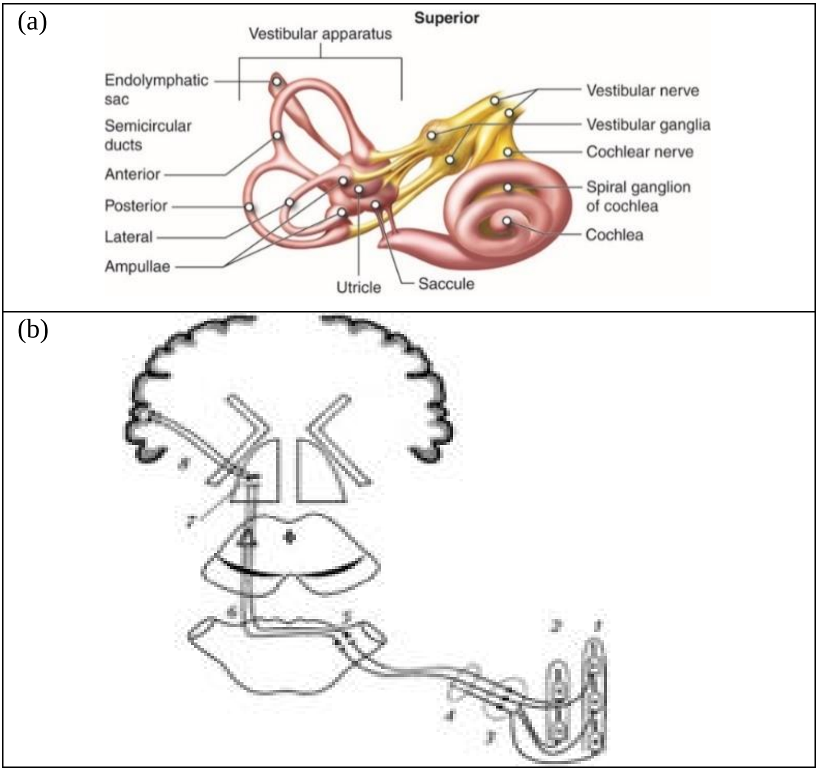

Figure 12: (a) Structures of the Vestibular Apparatus. This work by Cenveo is licensed under a Creative Commons Licence 3.0. (b) Neural connections of the vestibular sensory system to the brain: (1) crista ampullaris; (2) the vestibular sacs: the saccule and utricle; (3) vestibular ganglion; (4) vestibular part of the vestibulocochlear, or eighth cranial, nerve; (5) vestibular nuclei (II); (6) axons of second neurons; (7) thalamic nucleus; (8) thalamocortical radiations/fibers; (9) cortex of the parietal and / or temporal lobes.

Figure 12 illustrates the components of sensitive vestibular network and the many neural connections from the vestibular sensory system to the brain.

The otolith organs of the vestibular system are positioned in the direct path of radiation from a cell phone when it is held up against the ear. Thus, when a cell phone is used, a large number of the sensory receptors are irradiated by RF-EMFs.

In spite of its vulnerability, the FCC considers the inner ear to be on par with the limbs of the body when determining the allowable RF-EMF power density or SAR value. The FCC has decided that the ears are just like the limbs, hands, wrists, feet and ankles, and therefore need less stringent regulations than the rest of the body. The unfortunate consequence of equating the ears to the extremities, is that only local, thermal effects are included for consideration. Surprisingly, the FCC has not discerned the significance of the location of the ears due to their close proximity to both the brain and the inner ear. Nor has the FCC distinguished the ear's vital functional roles from that of the hands, wrists, feet and ankles. The FCC has ignored these important facts in its establishment of a less stringent SAR level, even though it is very clear that any radiofrequency field in this region of the body directly affects the brain.

Is it possible that low-intensity RF-EMFs affect brain function?

There is a long list (and history) of scientific research on this question, both in Russia and a number of other countries.

In Russia, as early as 1960, results from an experiment on rabbits indicated that brain activity is suppressed during local EMF irradiation, and that there is a direct effect on brain structures (Livanov et al., 1960). One year later in the USA, Frey suggested that RF-EMF can have a direct effect on brain cells (Frey, 1961).

In examining the question of effects on the brain from mobile RF-EMF-producing devices, we must include the pioneering contribution made by Yu A. Kholodov in the 1970s, who conducted a series of large-scale experimental studies on rabbits. The results obtained from these studies allowed the author to formulate the following principles regarding disorders resulting from cumulative bioeffects under repeated EMF exposures:

- the emergence of biological adaptive processes;
- the role of glial cells and disruption of the blood brain-barrier in the development of brain reactions under prolonged EMF stimuli (e.g., disruption of training and memory);

- the role of receptors in the implementation of the bioeffect;
- the possible influence on behavioral reactions;
- the development of conditioning effects under the combined action of EMF and other physical environmental factors,
- the presence of a direct EMF action on the brain (Kholodov, 1964; Kholodov, 1975; Kholodov, 1999).
- The direct action of EMF on the structures involved in central nervous system regulation. This makes the reaction to EMF different from the usual reaction to traditional stimuli which occurs via the sensory reflexes (Kholodov, 1988).

Professor Yu. A. Kholodov

To understand the interaction of RF with the brain, it is necessary to draw attention to a large number of electrophysiological studies by R.A. Chizhenkova. In examining the neuro-bioeffects of RF-EMFs, Chizhenkova considered the biopotentials of various brain structures under the action of microwave EMR, and concluded that:

> *the previously obtained changes in the bioelectric activity of the brain are the result of the direct action of microwave radiation on the cortex of the large hemispheres, which can lead to a violation of the transmission of information to more complex brain structures* (Chizhenkova, 2003).

In the following section, we focus on analyzing a series of studies on the effect of RF-EMFs on the brain, which were performed at the Institute of Biophysics of the Ministry of Health of the Russian Federation (USSR), in the laboratory of Professor Yuri Grigoriev from 1977 onwards.

At the Institute of Biophysics (with the assistance of the Director, Leonid A. Ilyin, a highly esteemed Academician within the RAS), we developed a modern technical foundation for experimental animal and human volunteer studies.

Academician Leonid A. Ilyin

Several anechoic chambers were built, which were equipped with EMF generators that were able to create various complex RF signal modes with frequency and amplitude modulations, and where the exposure could be delivered with intermittent low frequency pulses. We could then generate a simultaneous exposure to several different carrier frequencies at once. All cameras in the chambers were lined with a radiation-absorbing material with an absorption coefficient of 30 dB. All anechoic chambers were equipped with a modern electroencephalogram (EEG) apparatus and ECG heart rate monitors to record physiological reactions during provocation experiments.

One of the objectives was to obtain data that would describe the progression of development of brain responses to low-intensity RF-EMF exposure. This would allow us to ascertain whether the brain should be considered a critical organ when assessing the risk of RF-EMFs and standardizing limits for the public. The results and conclusions of these findings were presented by Professor Grigoriev in two monographs, in many articles (both domestic and foreign), and also at foreign congresses, conferences and specialized symposia (Yu. G. Grigoriev & Grigoriev, 2013; Yu. G. Grigoriev & Khorseva, 2014).

Electrophysiological effects on the brain

Studies were conducted primarily to assess the electrophysiological impacts of low intensity RF-EMFs on the brain. A large number of these studies were carried out by Professor Lukyanova. In each case, it was found that *changes in brain bio-currents* were elicited as a response. The results of these studies were presented in numerous publications e.g., by Grigoriev and Grigoriev in *Cellular communication and health. Electro-magnetic environment, radiobiological and hygienic problems, hazard forecast* (2013) and in Lukyanova's monograph *Electromagnetic Field of the Microwave Range of Non-thermal Intensity as an Irritant for the Central Nervous System* (2015).

Professor S. N. Lukyanova

It had already been shown that *bioelectric reactions* occur in the brain under short-term RF-EMF exposures of very low intensity. However, the shifts in the brain's bio-currents did not go beyond the normal level of functioning. Notably, the most pronounced changes occurred in the hippocampus, and were related to the Delta range (1-3 Hz). As a rule, results repeatedly revealed a direct relationship between the power density exposure value and the response. The effect seen most often in these studies of brain neurons under RF-EMF exposure, was the inhibitory response.

Study data showed that RF-EMFs can have a synchronizing effect on brain wave activity. A direct relationship was established between RF-EMF exposure with specific modulations or with more complex electromagnetic signal modes and the development of epileptic convulsions (Yu. G. Grigoriev & Sidorenko, 2010).

Modulated signals imprinted on the brain

In our laboratory, we began conducting experimental studies on chickens to investigate the effect of EMF irradiation on memory formation (Yu. G. Grigoriev, 1996; Yu. G. Grigoriev & Stepanov, 1988, 2000). We used the *imprinting* model (see below). This was a first. Before this work, no one had used imprinting to study the biological effects of EMFs.

Imprinting is an innate form of behavior that is crucial for survival. It is a specialized form of learning in animals that occurs during a critical period of their development. Imprinting involves the establishment of a bond between the newborn and certain objects in its external environment. This bond can be expressed, for example, by following any moving object, approaching it, making contact, or making sounds. In order for this reaction to manifest itself, the newborn organism must first receive a stimulus from the external environment. Such a stimulus is normally the first object the newborn comes into contact with, and under natural conditions, the parents are that object. If the newborns are separated from their parents, they will become attached to any indifferent substitute.

The imprinting attachment manifests itself in the first hours of life (the critical period) regardless of conditions such as the presence (or absence) of food and water. Through the study of imprinting, we can understand important behavioral reactions that are formed in animals immediately after birth. Imprinting, as a memory model, has been a topic of detailed scientific investigations involving many years of systematic research that has revealed the fundamentals of the neural basis of imprinted information (memories) on behavior (Horn, 1985).

Our laboratory imprinting experiments were conducted using 231 chickens. It was found that the early memory function of imprinting was reduced when chicken embryos were irradiated with low levels of pulsed RF-EMF modulations at 10 Hz and 40 Hz but not with continuous exposures (Yu. G. Grigoriev, 1996; Yu. G. Grigoriev & Stepanov, 1988). A clear dose-response relationship was found. Within these experiments, we also investigated whether certain RF-EMF frequency modulations could be imprinted on the brain. It was revealed that the RF-EMF *has a direct action on the brain* (thereby confirming the research findings of Livanov and Frey described above). Based on these studies, it was concluded that the brain not only responds to the stimulus of low-intensity RF-EMF but it is also able to remember (fix) the mode of the electromagnetic exposure.

Following these experiments, adaptive behavior and neurochemical reactions of the central nervous system were studied in small laboratory animals (mice and rats of different ages) after exposure to modulated RF-EMF (Shtemberg, Uzbekov, Shikhov, Bazian, & Cherniakov, 2000). Frequencies were those used in modern telecommunications (4.2 GHz and 970 MHz) and power densities were ultra-low at 15 $\mu W/cm^2$. The nature of the animals' spontaneous behavior in an open field was studied for various exposure durations ranging from 15 to 120 minutes. In control animals (sham condition), stereotypical patterns were observed; i.e., there was a change in exploratory activity due to the initial fear reaction, followed by the extinction of this reaction. In irradiated animals, however, the dominance of the fear response persisted throughout the experiment, inhibiting the tentative exploratory activity and slowing down the processes of adaptation to the experimental environment. No clear dependence on the duration of the exposure was found.

Consistent with the decrease in motor activity, a significant 4-fold decrease in the level of norepinephrine in the motor cortex was measured in the irradiated animals compared to the control. This effect was found at 970 MHz after a set of neurotransmitters (monoamines, norepinephrine, dopamine, serotonin) and some of their metabolites (dihydroxyphenylacetic acid and 5-hydroxyindoleacetic acid) were investigated. Changes in the content of dopamine, serotonin and their metabolites were unreliable.

Prior to this work, in the 1980s, Russia and America had conducted a joint research project on the biological effects of RF-EMFs as part of a Soviet-American agreement to cooperate in the field of environmental protection. The research groups were the National Institute of Environmental Health Sciences or NIEHS) in the United States, and the A. N. Marzeev Institute of General and Communal Hygiene in Kiev in the USSR (as Russia was then known). A synchronous experiment was conducted in both countries to assess the possible impact of RF-EMFs on the central nervous system (Mitchell, Makri, et al., 1989 (in Russian); Mitchell, McRee, et al., 1989 (in English)). The experiment was carried out on rats using a continuous 2.45 GHz exposure with a power density of 10 mW/cm^2 for 7 hours. After irradiation, exposed and control animals were compared for their behaviors of passive avoidance and movements in the open field.

Both research groups found no differences between the control and exposed groups for any of the behavioral indicators. Based on previous studies, these results were unexpected. They were explained by Michell, McKree et al (1989) as possibly due to the strains of rats used in the joint study being different to those used in previous studies.

Western research into adverse effects from low-intensity RF-EMFs

A number of studies outside of Russia also recorded reactions in the brain after short-term exposure to low-intensity RF-EMFs. First, Professor Lai and his colleagues demonstrated that cognitive impairment occurs after a single low-intensity RF-EMF exposure (Lai, Horita, & Guy, 1994).

Professor Henry Lai

Then Lai & Singh demonstrated that exposure to short term, low intensity RF-EMFs breaks single strands of DNA in the brain, leads to oxidative stress in the biological systems of the brain due to an increase in free radicals, and affects the antioxidant defence systems. These effects can be blocked by prior treatment with melatonin, a powerful antioxidant (Lai & Singh, 1995, 1997).

Effects on the blood brain barrier

For twenty years from 1988 onwards, Professor Leif Salford, led a series of studies examining the effect of mobile phone EMFs on changes to the permeability of the blood-brain barrier (BBB) in rats. These results were first published in the 1990s (Salford, Brun, Sturesson, Eberhardt, & Persson, 1994; Salford, Persson, & Brun, 1997).

Professor Leif Salford

Special anechoic chambers, (transverse electromagnetic transmission line chambers, or TEM-cells) were used. Two rats were placed in each cell, with one rat in the upper compartment, and the other in the lower one. RF-EMFs were applied from a directional antenna located in the upper part of the anechoic chamber. Figure 13 shows how each animal was kept in compartments under unrestrained conditions.

Figure 13: The experimental setup of Professor Salford showing TEM-cells (Salford, various publications)

Some of the short-term RF-EMF exposure studies initiated by Salford and his colleagues used a continuous wave (CW) mode of generation, while others had a more complex mode, using electromagnetic pulsing. For example, various modes of 915 MHz EMF irradiation were used in continuous mode, or in pulsed modulation mode using repetition rates of 4, 8, 16, 50 and 217 Hz. In most experiments, the duration of exposure was 2 hours; however, in some experiments, the exposure was 16 hours. The effect of the exposure duration was found to be insignificant. In total, experiments were performed on 1,002 rats (630 experimental and 372 control rodents).

Short term effects: In Salford's earlier experiments, the animals were sacrificed between 20 and 120 minutes after irradiation. The data showed that immediately after exposure to EMF with a continuous wave frequency, the permeability of the BBB increased. These changes were observed in more than 50% of the irradiated animals.

Long-term effects: In further studies, the state of BBB permeability was again evaluated by Salford and his colleagues, but with longer time periods between exposure and sacrifice (Eberhardt, Persson, Brun, Salford, & Malmgren, 2008; Nittby, 2008; Salford, Brun, Eberhardt, Malmgren, & Persson, 2003). A mobile phone was used for irradiation with a frequency of 915 MHz under the previously described conditions. The peak power in the anechoic chamber was 1, 10, 100 or 1000 mW/cm^2, and the SAR was 0.12; 1.2 or 12 and 120 mW/kg). The animals were sacrificed immediately or after a longer period of time at 7, 14, 28 or 50 days after a single EMF exposure for 2 hours.

The results of the experiments showed that, both immediately after irradiation, and after 7, 14 and 50 days, there was an increased permeability of the BBB for albumin (described in more detail below). Moreover, the dynamics of changes in permeability from the elapsed time after irradiation had a wave-like character; i.e., on days 7 and 14, the BBB permeability increased, on day 28, there were no changes in the BBB permeability, and on day 50, the permeability for albumin increased significantly.

Salford and his colleagues further showed that the increase in BBB permeability resulted in damage to neurons. For example, Salford et al. (2003) detected albumin leakage and subsequent damage to neurons in the cerebral cortex, hippocampus and basal ganglia 50 days after a single 2-hour exposure to GSM mobile phone EMFs These experiments were performed on 32 Fischer rats aged 12-26 weeks using SAR exposures of 2, 20 and 200 mW/kg.

Building on this finding, Eberhardt et al. (2008) showed that significant changes in the BBB permeability occurred 14 days after exposure, while damage to neurons (see below) occurred at 28 days ($p<0.001$). This experiment used 48 irradiated rats and 48 control animals, 217 Hz modulation, GSM standard, and SAR exposure levels of 0.12, 1.2, 12, or 120 mW/kg.

Albumin penetrates into brain tissue and accumulates in neurons, in glial cells, and around blood capillaries. Albumins are a type of globular protein that are found in the blood that have been shown to have a neurotoxic effect when they penetrate the BBB. When these are introduced into the rat-brain parenchyma, the neurons are damaged. In the irradiated animals, a definite albumin reaction was observed around small vessels in the white and grey brain matter.

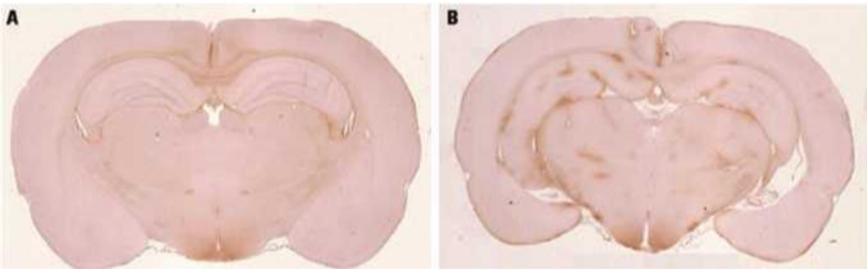

Figure 14: Cross-section of central parts of the brain of: (A) an unexposed control rat and (B) an RF-EMF exposed rat, both stained for albumin, which appears brown (Salford et al., 2003). In (A), albumin is visible in the central inferior parts of the brain (the hypothalamus), which is a normal feature. In (B), albumin is visible in multiple small foci representing leakage from many vessels.

Albumin antibodies were used in histochemical analysis (see Salford, Brun, Eberhardt, Malmgren, & Persson, 1992). The reaction manifested itself as brownish mottled formations or as scattered discolorations. The albumin had spread between the tissue and surrounding neurons. Cresyl violet staining showed the presence of damaged neurons, which were often wrinkled and dark in color, with a homogenized loss of visible internal cell structures. Salford et al. called these “dark neurons”. Some of the dark neurons were albumin-positive or contained cytoplasmic microvacuoles, which were interpreted as indicating the presence of an active pathological process (Figures 14 and 15).

The percentage of abnormal neurons was roughly estimated at a maximum of 2%, but in some limited areas they were dominant. The dark neurons were found in many locations of the brain, but were most common in the cerebral cortex, hippocampus, and basal ganglia, and were scattered amongst normal neurons. These resulting changes were highly significant ($p>0.002$).

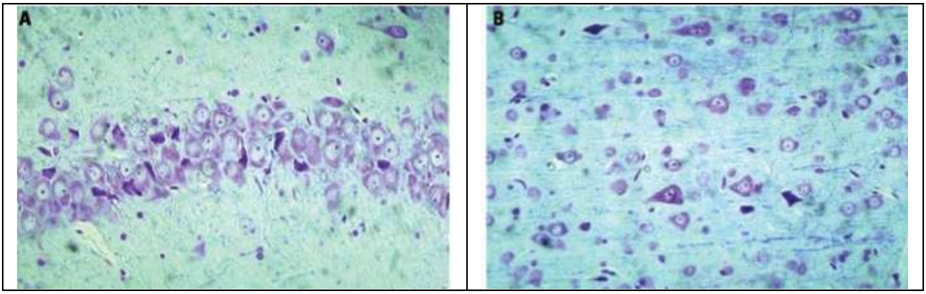

Figure 15: Photomicrograph of sections of brain from an RF EMF-exposed rat stained with cresyl violet (A) Row of nerve cells in a section of the pyramidal cell band of the hippocampus; among the normal nerve cells (large cells) are interspersed black and shrunken nerve cells, so-called dark neurons. (B) The cortex of an RF EMF-exposed rat showing normal nerve cells (pale blue) intermingled with abnormal, black and shrunken “dark neurons” at all depths of the cortex, but least in the superficial upper layers (Salford et al., 2003).

These results show that a single exposure to the EMF of a mobile phone can lead to a significant leakage of albumin through the blood-brain barrier. Moreover, while there was a significant positive relationship between EMF dosage (SAR) and the number of dark neurons, the magnitude of the neuronal damage did not depend directly on the SAR value. Rather, it was manifested at varying degrees in the time span after the irradiation. This is an example of an important fact that is vital to understanding when creating RF-EMF standards: that biological systems are not linear.

When summarizing these results, Salford made the following statement:

> *We present here for the first time evidence for neuronal damage caused by nonthermal microwave exposure. The cortex as well as the hippocampus and the basal ganglia in the brains of exposed rats contained damaged neurons. We realize that our study comprises few animals, but the combined results are highly significant and exhibit a clear dose–response relation* (Salford et al., 2003, p. 882).

In some of their studies, Salford and his colleagues also showed effects of exposures on cognitive function (Nittby et al., 2008) and episodic memory and gene expression (Nittby, 2008).

Salford suggested that mobile phone users may have accelerated "brain ageing". From a radiobiological perspective, for assessing the risk of mobile phone EMFs, the authors attained a pertinent observation: a direct relationship between the number of "dark neurons" in brain tissues and a specific window of the SAR value.

The implications of this work are that the current standards are inadequate to protect against adverse effects. This is because the exposure thresholds set within the standards are founded on the assumption that the greater the power absorption, the greater the negative effect. Salford's work has shown that this linear dose-response relationship does not hold, because large effects have been demonstrated at very small doses.

Effects of longer exposures on proteins, DNA and brain cells

After sub-chronic exposures (lasting weeks to months), changes in the structure of proteins and changes in brain cells have been found.

Using sub-chronic exposure conditions, Kesari, Behari, and Kumar (2010) observed damage to rat brains, as indicated by an increase in DNA double-strand breaks and changes in antioxidant enzymes (which are used for removal of free radicals). These changes were found after the male Wistar rats had been irradiated for 2 hours per day over 35 days with 2.45 GHz at 0.35 mW/cm^2 and whole-body SAR levels of 0.11 W/kg.

Also using sub-chronic conditions, Ammari et al. (2010) found an increase in the presence of astrocytes in different brain areas. Rats were exposed five days per week for eight weeks to 900 MHz RF-EMF. One group of rats was irradiated for 45 minutes per day at lower SAR levels of 1.5 W/kg, and two groups of rats were irradiated for 15 minutes per day at higher SAR levels of 6 W/kg. After the exposure period, effects were found on days three and ten in the level of glial fibrillary acidic protein (an indicator of brain cell damage) in all three experimental groups. According to the authors, this result indicated an adverse effect on the brain of EMF mobile phone irradiation; i.e., potential gliosis.

Sub-chronic exposure regimes have been used to investigate damage to the hippocampus, which has been implicated in learning and memory degeneration. The possible effects of mobile phone use on calcium homeostasis in the hippocampus was investigated by Maskey, Kim, et al. (2010). Mice were irradiated for 1 hour per day for 5 days at SAR levels of 1.6 or 4.0 W/kg, or for 1 hour per day for one month at SAR levels of 1.6 W/kg. The different regions of the hippocampus were then inspected for signs of neuronal damage and changes in the expression of two calcium binding proteins, Calbindin and Calretinin. The results showed an almost complete loss of pyramidal cells in the CA1 region of the hippocampus in the mice who has been exposed for a month-long period. The authors suggested this may explain the behavioral, learning and memory deficits observed with EMF exposures. Furthermore, the authors proposed that the sustained EMF exposures caused changes in the expression of calcium binding proteins, which caused changes in cellular calcium levels, which then affected the signalling between cells, resulting in a deterioration in neuronal connectivity and integration in the hippocampus.

In a related set of experiments Maskey, Pradhan, et al. (2010) investigated the possible effects of mobile phone use on proteins and cell death in the hippocampus. Rats were exposed 8 hours per day over a 3-month period to 835 MHz at low SAR exposure levels of 1.6 W / kg. The results showed a decrease in the immune reactivity of calcium-binding protein, damage to interneurons and pyramidal cells in the CA1 region, an increase in the immunoreactivity of glial fibrillary acidic protein (an indicator of brain cell damage) and apoptotic cells in certain areas of the hippocampus.

Overall these changes indicated that sub chronic RF-EMF exposures can result in damage to the hippocampus. Based on the results of these studies, an international expert commission within the Swedish Radiation Safety Authority (SSM) concluded:

> *Recent studies indicate that in rodents several weeks of daily exposure of 45 min or longer to a mobile telephone signal at a SAR of 1.5 W/kg and higher may result in a response in hippocampal neurons that indicates activation in response to injury. This might have an effect on memory and cognitive functions.* (Ahlbom et al., 2010 p. 28)

A number of papers published overseas in recent years, have also indicated that the brain shows a greater sensitivity after sub-chronic exposures (weeks or months) or chronic exposures (a year or more) to low-intensity RF-EMFs.
Dasdag et al. (2015) showed that chronic exposures can lead to changes in microRNA in the brain. In this experiment, rats were irradiated with an RF of 900 MHZ for three hours a day, seven days a week for one year. Exposures affected some of the micoRNA investigated. According to the authors, such micoRNA alterations (which are known to suppress one or more target genes) may be a basis upon which 900 MHz exposures can lead to adverse effects in the growth, differentiation, proliferation and death of cells.

Deshmukh et al. (2016) published research on the hazardous effects to the brain of sub-chronic RF-EMF exposures. This experiment exposed rats for 90 days to low SAR levels at 900, 1800, and 2450 MHz. Results showed a decline in cognitive function, an increase in heat shock protein 70 (Hsp70) and an increase in DNA damage.

Two related reports were published on the activation of autophagy in the cerebral cortex after longer exposures to RF-EMF. In a shorter experiment Kim, Yu, and Kim (2017) irradiated C57BL/6 mice for 5 hours daily for four weeks to 835 MHz RF-EMFs at SAR levels of 4.0 W/kg. Autophagy was induced in the cerebral cortex and apoptosis was activated in the brain stem. In a longer twelve-week experiment using the same types of mice and the same exposure regime, Kim, Yu, Huh, et al. (2017) found effects on cortical neurons such as hyperactivity, autophagy, an increase in autolysis (self-digestion) in neuronal cells and damage to the myelin sheath. The authors suggest that autophagy may act as a protective action while demyelination may be *a potential cause of neurological or neurobehavioral disorders* (Kim, Yu, Huh et al., 2017, p. 1).

Nittby (2008) conducted a series of experiments showing memory impairment in rats after exposure to cell phone irradiation for more than one year. Later in this book we will discuss further research on the effects of RF-EMF radiation on cognitive functioning in children.

The publications presented above clearly indicate that RF-EMFs from our cellular communication systems and cell phones result in adverse bioeffects on nerve structures of vital centers of the brain and the inner ear, thereby affecting their functioning. The evidence clearly indicates that there is a violation of the Blood Brain Barrier.

In spite of these results, the bioeffects of RF-EMF exposures to the brain have not been included in the current standards, and have been completely ignored when assessing radiation risks for users. Due consideration has not been given to the vulnerability and critical functioning of the brain. Furthermore, the additional functional load that is delivered to the brain from the skin receptors when they are exposed to MMWs has not been considered.

> *In our opinion there is sufficient evidence for us to acknowledge that there is a clear risk to the brain and nerve structures from exposure to RF-EMFs from 3G and 4G technology. This human health risk will increase with the introduction of 5G technology.*

The thyroid gland

As cellular antennas in many smartphones are located in the lower part of the mobile phone, exposure actually occurs in the neck area. There is therefore a risk to the thyroid gland and, as a consequence, the possibility of thyroid dysfunction and tumor development (Carlberg, Hedendahl, Ahonen, Koppel, & Hardell, 2016). In our opinion, children will suffer an increased risk given the shorter distance between the thyroid gland and the mobile phone antenna (see Figure 16).

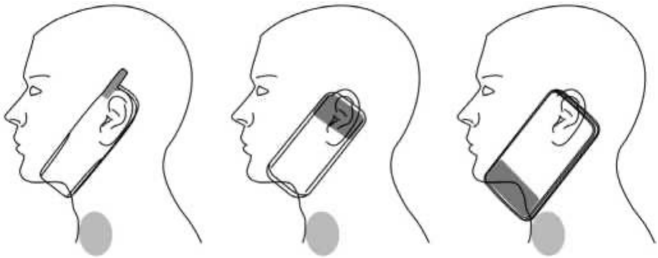

Figure 16: The position of the smartphone antenna in relation to the thyroid gland (Carlberg et al., 2016)

Dosimetric studies were conducted to calculate radiation exposure to the human endocrine glands of the neck and head area during cell phone use (Lu & Wu, 2016). The results showed that the energy absorbed in the thyroid gland (SAR) is far greater than in the glands of the head itself. However, the SAR exposure values in the thyroid gland during a phone call are within the maximum levels permitted by the IEEE standard, adopted by the USA (1000 $\mu W/cm^2$).

Studies have also shown that there are adverse impacts on the state of the thyroid gland due to exposures to pulse-modulated RF in mobile phone users. Changes in thyroid hormones and changes at the level of parenchyma (functional cells) and stroma (structural cells) have been detected, as described below.

Mortavazi et al. (2009) found an association between mobile phone use and changes to the TSH and thyroid hormones in healthy university students. (An abnormal level of TSH is a strong indicator of thyroid dysfunction). They concluded that excessive mobile phone use can result in *minor degrees of thyroid dysfunction with a compensatory rise in TSH* (Mortavazi et al. p 274) and that the changes in thyroid hormones were probably due to negative effects of the mobile phone signals on the hypothalamic-pituitary-thyroid axis.

Baby, Koshy, and Mathew (2017) also found a significant correlation between mobile phone use and thyroid dysfunction in students. Out of 83 students, clinical examination showed that 13.6% had palpable thyroid swelling, 3.6% had symptoms of thyroid dysfunction, and 3.6% had symptoms of thyroid swelling and dysfunction. Self-reports of phone use in survey responses showed that over half (53%) of the respondents spent an average of 0.5 hours talking on the phone each day; 28.9% spoke for 1.5 hours a day, and 10.8% reported talking for over 3.5 hours per day. There was a significant correlation between an increase in TSH and total radiation exposure (calculated using SAR ratings for type of phone and time spent on mobile phone). This is consistent with the findings of Mortavazi et al, described above.

Exposure to RF pulse-modulated EMFs has been shown to cause changes in gland structure and thereby induce hypothyroidism and apoptosis in thyroid cells (Eşmekaya, Seyhan, & Ömeroğlu, 2010). These changes occurred in a study that exposed Wisar rats to a typical GSM exposure regime; i.e., 900 MHz, for 20 minutes per day for three weeks, at a SAR level of 1.35 W/kg. Thyroid hormone secretion was inhibited by exposure. Thyroid hormone disruption and degree of pathology were observed via an increase in the height of the thyroid's follicular epithelium, a change in the colloid content of the follicles, and apoptotic death of thyrocytes (the thyroid epithelial cells which produce the thyroid hormones). Furthermore, transmission electron microscopy was used to measure markers of cell death (caspase-3 and caspase-9). The activity of these markers indicated reduced protection against thyrocyte death. The authors concluded that whole body exposures to GSM signals over a long-period of time can result in pathological changes to the thyroid.

A systematic review of publications up to December 2018 was conducted to evaluate the evidence regarding the effects of mobile phone radiation on thyroid cells and hormones (Asl et al., 2019). While the majority of studies investigating the T3 hormone showed increases, one showed a decrease. There were also different outcomes for T4 and TSH. However, studies investigating histological changes in thyroid follicles consistently found a reduction in the volume of these cells. The authors suggested that RF radiation may either negatively affect the utilization of iodine by the thyroid gland or RF may increase the effect of temperature on the thyroid gland, which then adversely affects the thyroid's regulatory function.

Silva et al. (2016) found no effect from cell phone-like electromagnetic radiation on thyroid cells *in vivo*. However, it should be noted that the exposure doses used in the experiment were very small. While SARs close to the ICNIRP thresholds were used (0.08 W/kg and 0.17 W/kg) the exposure durations only ranged between 3 and 65 minutes. Deleterious effects on the thyroid may become more apparent after longer exposure times.

Russian scientific publications by Vorontsova have also found evidence of adverse impacts of RF-EMF exposures on the function of the thyroid gland, in experiments using freely-moving rats (Z. A. Vorontsova, 2004; Z.A. Vorontsova, Dolzhanov, & Zuev, 1999). After a five-month exposure to pulsed RF-EMF irradiation, the activation of hormone production was detected through the degree of iodization of amino acids in the colloid of the thyroid follicle. The inhibition of thyroid hormone excretion into the blood was observed Reduced thyroid hormone is known to have serious health consequences (Kapil, 2007). The most pronounced effect of adversely affected thyroid function was found after ten months of exposure to RF-EMFs. The follicles exhibited an increase in the number of proliferative papillae, while the thyroid epithelium was flattened and lost its functionality. Particular types of mast cells of the thyroid stroma showed a sensitivity to electromagnetic exposure. These mast cells regulate local homeostasis processes. Overall, the results showed that the quality and quantity of biologically active substances released by these mast cells was modified, depending on the duration of exposure to RF-EMFs.

An examination of the published research results on this topic suggests that electromagnetic fields can lead to a high risk of thyroid disease such as hypothyroidism, or carcinogenesis, inducing changes to the whole body.

> *We expect that increased exposure to complex RF-EMFs, such as frequency and amplitude modulations as well as new exposures to 5G millimeter waves, will bring a concurrent increase in adverse effects to the thyroid gland (Cherkasova, S., & A., 2011; Yu. G. Grigoriev & Grigoriev, 2013; Yu. G. Grigoriev, Vorontsova, & Ushakov, 2020).*

The immune system

Over the last 50 years, a multitude of studies have been performed to assess the possible effects of RF-EMF on the immune system. The underlying purpose of these endeavours was to assemble a research database that could be used to develop a scientific foundation for the creation of RF-EMF exposure standards. Most of the Russian research in this area was carried out from 1973 to 1987 by colleagues at the A. N. Marzeev Institute of General and Communal Hygiene in Kiev, under the guidance of M. G. Shandala, an Academician of the Russian Academy of Sciences. As a result of this work, it was concluded that low-intensity RF-EMFs can have an adverse effect on immunity.

Adverse impacts on immune system functioning were found for sub-chronic RF-EMF exposures (two months) at a power density of 500 $\mu W/cm^2$ (Shandala & Vinogradov, 1982; Shandala, Vinogradov, Rudnev, & Rudakova, 1983; Vinogradov & Dumansky, 1974; Vinogradov & Naumenko, 1986). The adverse effects found in these experiments included the following: autoimmune effects and their effect on the fetus and offspring; changes in the antigenic properties of tissues and autoimmune processes; and changes to some indicators of cell-mediated immunity.

Russian-French joint research overseen by the WHO

To replicate the above-mentioned studies, Russian colleagues initiated joint Russian-French experiments. These were conducted with the support of the WHO, at the Burnasyan Federal Medical Biophysical Center (a Russian State Research Center [SRC-FMBC] of the Federal Medical Biological Agency [FMBA]). In these experiments, the exposure methods were kept as similar as possible to the aforementioned experimental studies, but now the modern ELISA method (see below) was used. Additionally, modern conditions for exposure to RF-EMFs and dosimetry methods were created. The rationale of the joint venture was to confirm the earlier Russian studies. To do this, it was necessary to show, under rigorous conditions, that sub-chronic exposure to RF-EMFs of a non-thermal intensity would affect the number of antibodies active against antigens in various somatic organs (the brain and the liver).

M. G. Shandala
Academician of the Russian Academy of Sciences

Rigorous experimental design protocols

Preparatory work for the experiments was initiated in 2005. Procedures and protocols were developed with detailed descriptions for all stages of the study. Protocols were subsequently approved by the WHO, and by an independent International Oversight Committee that included expert scientists from the United States, Italy and Germany.

Appropriate specialists were selected for the research teams in accordance with the profile of the research plan. The Russian-French research group, together with the International Oversight Committee, agreed on the conditions of exposure to RF-EMF, which were subsequently implemented. The exposure doses were confirmed at the time of irradiation by dosimetric studies conducted with the assistance of French experts. Each animal in the exposed groups received an equal dose of absorbed radiation. This was guaranteed by the irradiation method used, which created a uniform electromagnetic field.

To ensure impartiality in these experiments, a neutral radiobiological laboratory was used (at the Institute of Biophysics, headed by Professor Darenskaya). This laboratory worked with the animals during their entire 30-day irradiation period and also their subsequent 14-day quarantine. The employees of the laboratory were unaware of the details of the experiment. Furthermore, they worked with material that had been encrypted by other participants. This ensured their blind (impartial) participation since they were unable to anticipate any experimental outcome in their work.

The entire experimental process, from the processing of the samples obtained, to the analysis of results and the consequent formulation of a conclusion, was carried out with the active participation of the International Oversight Committee, and with the involvement of the former head of the WHO's Electromagnetic Fields (EMF) Project, Dr Michael Repacholi. It was completed in three years (2005-2007) by a research team led by Professor Grigoriev, in accordance with the WHO protocols and under the auspices of the International EMF Project.

The report on the results of these experiments and its general conclusions were approved by WHO and the International Oversight Committee. The major findings were published in a series of five publications in the Russian journal, *Radiation Biology, Radioecology* (Yu. G. Grigoriev, F., et al., 2010; Yu. G. Grigoriev, Grigoriev, Ivanov, Lyaginskaya, Merkulov, Stepanov, et al., 2010; Yu. G. Grigoriev, Grigoriev, Merkulov, Shafirkin, & Vorobiov, 2010b; Ivanov et al.; Lyaginskaya, Grigoriev, & Osipov, 2010) and also internationally (Yu. G. Grigoriev, 2011; Yu. G. Grigoriev, Grigoriev, Ivanov, Lyaginskaya, Merkulov, Shagina, et al., 2010; Yu. G. Grigoriev, Grigoriev, Merkulov, Shafirkin, & Vorobiov, 2010a; Lyaginskaja, Grigoriev, Osipov, Grigoriev, & Shafirkin, 2010).

The first part of this joint project experiment investigated whether sub-chronic RF exposures would have an effect on the immune response of rats. The second part of the experiment investigated whether the immune response from rats who were exposed would produce negative outcomes for other, pregnant rats (when serum from the exposed rats was transferred to the pregnant rats). The methods and results for of both parts of the experiment are described below.

Phase 1: Immunological effects

The first phase of the experiment investigated the immunological effects of sub-chronic (1 month), low intensity EMF exposures.

Protocols: Phase 1 of the experiment used 48 Wisar rats, divided into three equal groups of 16, comprising the exposed, sham and biocontrol rats. The exposed rats in were irradiated for a protracted period of time (so as to simulate sub-chronic exposure) for 30 days, seven hours a day, five days a week. On day 7 and day 14 after the irradiation period, 5 then 11 rats respectively were used from each group to prepare samples for the subsequent immunological tests. The day 14 rats were also used as donor rats for Phase 2 of the experiment (described later). In all cases, blood was taken, serum was prepared, the animals were sacrificed, and then antigens were obtained from the rats' brain and liver tissue.

Conditions: In the experiment, rats in both the real the sham exposure conditions were placed in separate, shielded anechoic chambers. Inside these chambers were specially designed enclosures that formed a ring of 16 pens, with one rat in each pen (see Figure 17). Thus, there was one ring of sham rats and one ring of exposed rats. The rats were not restrained in the pens, which were fitted with transparent lids. All 16 pens were the same size, with dimensions of 32 cm x 15cm.

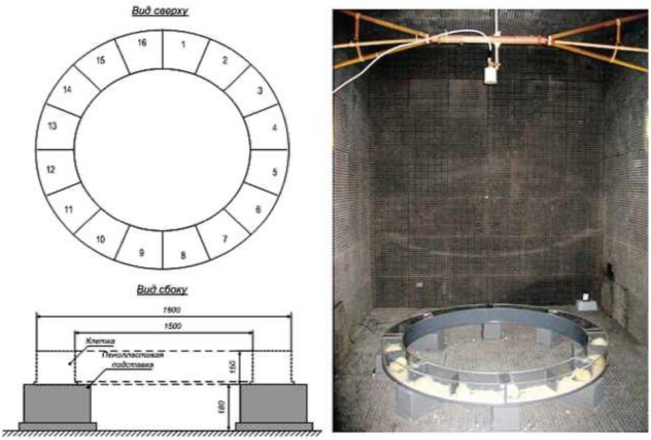

Figure 17: General view of the experimental setup for irradiation of rats in an anechoic chamber

After the irradiation or sham exposure each day, the rats were taken to the vivarium where they were kept in a separate special room at an air temperature of 21-23°C, a relative humidity of 40-60%, under artificial light for 12 hours a day and a ventilation rate of 100 m^3/h.

The 16 exposed rats were irradiated using a continuous, elliptically polarized, 2450 MHz signal at a power density exposure of 500 μW/cm^2. The source of this RF-EMF was the *LUCH-11* diathermy apparatus, which generated continuous electromagnetic oscillations with a frequency of 2450±50 MHz. The average power density exposure values were measured using a German Narda EMR-20 meter connected to a computer. The power density exposure values that were recorded ranged from 429 to 593 μW/cm^2 with an average value of 495 μW/cm^2.

Dosimetric calculations of the RF-EMF intensity were performed by an accredited expert, Dr Philippe Leveque, from XLIM, a multidisciplinary research institute in Limoges, France. SAR values were measured using the FDTD (Finite Difference Time Domain) method. A digital model of the rat had been developed at the (former) Brooks Air Force Base research laboratory (San Antonio, USA) which consisted of 36 different types of biological tissues with a resolution of 0.75 mm. The SAR averaged over the entire body was measured at 0.16±0.04 W/kg with an incident field power density exposure of 500 μW/cm^2. The average SAR value measured over brain tissues was close to 0.16 W/kg. The maximum SAR value for the brain tissues was 1.0 W/kg. Thus, all exposures were around 50% of the ICNIRP thresholds). Changes in average SAR values did not exceed 5% for different positions of rats in cages.

Background

Results from the earlier Russian studies had revealed evidence that either non-typical brain tissue antigens had been produced, or there had been an alteration in the structure of normal antigens produced as a result of sub-chronic RF exposures. Furthermore, the exposed rats had also produced antibodies specific to these non-typical antigens. Overall, the results indicated that the exposed rats had produced immune responses that were specific to the RF exposures.

The joint experiment was an attempt to replicate these results under the rigorous conditions described above. Phase 1 of the joint experiment investigated the formation of antibodies in the brain and liver tissues of rats as a result of sub-chronic RF exposures.

RF-specific antibodies

If the organs of a host animal encounter adverse circumstances, this will result in antigens being present in these organs. Antibodies are proteins that are then produced by the immune system to fight the antigens. The normal immune response is for antibodies to bind to the antigen, creating an antigen-antibody complex. The antibodies then bind plasma proteins called "complement" onto this complex. (This process is called "complement fixing"). The complement proteins then trigger a cascade of immune system responses on the surface of the pathogen in order to fight it. The antibodies are then transferred to the lymphatic system via the blood. Antibodies are produced slowly, so that it takes about two weeks after an antigen invasion or mutation for antibodies to be detected in blood serum.

In order to look for the presence of antibodies, the Complement Fixation Assay (CFA) method is often used. This method first introduces tissue containing antigens into blood serum of the affected animal. If the donor animal has experienced adverse conditions, then specific antigens will be present in the introduced tissue (e.g., brain tissue). In a similarly affected animal, antibodies specific to these antigens would have been first created in the body tissue (e.g., the brain) where the antigens first appeared. Then these antibodies would have been sent to the lymphatic system via the blood. These antibodies would then be present in the recipient's blood serum, to work against the antigens appearing in the introduced tissue. Such antibodies are called "anti-tissue antibodies".

The CFA method uses the fact that if more anti-tissue antibodies are present in a blood serum sample, they will use up more complement from the blood (in their response to the antigens in the affected tissue). Thus, the amount of complement that is "fixed" in a sample is used as a measure of how much antibody activity has been produced by the recipient's immune system in response to an adverse event (such as the introduction of antigens).

In this experiment, the source of antigens was tissue that was taken from each rat's own RF-exposed brain and liver. This tissue was introduced into the aqueous blood serum extract for that rat. The amount of complement that was subsequently fixed was used as a measure of how much antibody activity had occurred in that rat's brain and liver during and after the exposure period.

Results: If the RF exposures had produced adverse effects, then more anti-tissue antibodies would be observed (via more fixing of complement) in the blood of exposed rats compared to sham or control rats. This is indeed what was observed. On the 7th day after the exposure regime had ended, the levels of both brain and liver anti-tissue antibodies were found to be slightly greater in the exposed group (brain log titer 0.68±0.18; liver log titer 0.54±0.23) than in the biocontrol group (brain log titer 0.34±0.21; liver log titer 0.28±0.17). (A titer is a laboratory test that measures the presence and number of antibodies in blood.) On the 14th day after the exposure regime had ended, the brain anti-tissue antibodies had increased in the exposed group of rats (log titer 1.19±0.07). These levels were statistically greater that those of the sham animals (log titer 0.89±0.05) and those of the biocontrol group (log titer 0.69±0.08). On this same day, the level of liver anti-tissue antibodies was also slightly greater in the exposed group (log titer 0.44±0.13) than in the biocontrol group (log titer 0.06±0.06).

Overall, the sham group showed similar increases to the exposed group in the number of brain anti-tissue antibodies on day 7 after the exposure regime had ended, probably due to the stress on rats in both groups created by restricted movement. However, on day 14 after the exposure regime had ended, the exposed rats showed an additional significant increase in brain anti-tissue antibodies, over and above that of the sham rats. These day 14 increases were likely due to the RF exposures.

The results obtained showed a similar same pattern of results to those that had been found in the earlier Russian studies (described above). However, in this later experiment, the increase in anti-tissue antibodies in the exposed group was less pronounced than in the earlier studies.

Antibody levels for specific, known antigens were also evaluated using the modern ELISA method (enzyme-linked immunosorbent assay analysis), which used plates loaded with known antigens in order to see if they elicited antibody activity in the blood serum.

The ELIZA method showed an increase in the levels of antibodies working against most of the 16 tested antigens. In particular, antibodies triggered by antigens fatty acids or containing the nitrogen oxides NO and NO2 were more present in the serum of the exposed group than in the serum of the sham group. The antibodies that reacted to these conjugated antigens in the brain and liver serum were mostly IgM and some subclasses of IgG, but no IgA antibodies were visibly detected. The levels of these antibodies were higher on day 7 compared to day 14 after the exposure regime had ended.

The formation of reactive oxygen species (ROS) and nitric oxide (NOS) signalling molecules normally occurs in response to adverse events. In this experiment, it is likely that the irradiated rat body reacted via the production of antibodies in response to ROS and NOS products. That is, the response to prolonged exposure to low-intensity RF-EMF *in vivo* was a set of intracellular stress reactions associated with the formation of reactive oxygen species (ROS) and nitric oxide (NOS) signalling molecules. The maximum effect was observed 7 days after the exposure to RF-EMF ceased. The severity of the effect had decreased by 14 days after exposure ceased.

The difference between the CFA and ELIZA tests is that the CFA method reveals the *level of antibody activity* in response to the exposure, while the ELISA reveals the *structure of the antigen components* created by the exposure. The ELIZA test can only gain information about antibody responses to known antigens. However, The CFA allows for the discovery of unknown antigens.

Overall, both the CFA and ELIZA tests revealed an increase in anti-tissue antibody activity in the group exposed to sub-chronic, low intensity levels of radiation.

Phase 2: Effects of RF-EMF on the course of pregnancy, foetal development and offspring

The second phase of the joint experiment aimed to investigate whether RF-EMR acts as a teratogen, thereby producing negative outcomes for the development of rat fetuses and offspring.

In 1982, the Russian researchers (Shandala & Vinogradov, 1982) had found autoimmune effects within exposed pregnant rats as well as an immune conflict with its fetus and offspring. First, rats were exposed for 30 days for 7 hours per day, with UHF radiation power density of 500 μW/cm^2 (i.e., 50% of the ICNIRP standard). Then, serum from the irradiated mice was injected into pregnant rats. The antibodies in the serum from the exposed rats affected the pregnancy of the injected rats, with higher mortality of the embryos and offspring.

The aim of the Phase 2 study was to reproduce these earlier results using more severe irradiation regimes and, thereby to confirm the possible damaging effect of antibodies from exposed rats on fertility, pregnancy, foetal development and offspring.

Protocols: Phase 2 of the joint experiment was performed from October 20, 2006 to February 10, 2007. The 11 donor rats from Phase 1 along with 49 additional, pregnant rats were used. Blood serum was obtained from the Phase 1 exposed and sham group rats 14 days after their 30-day irradiation regimen had ceased. This blood serum was then injected into the intact Phase 2 rats during their pregnancy. The subsequent course of pregnancy and the development of the fetus and offspring in the Phase 2 rats was observed, and the fertility of their offspring was also assessed.

The pregnant rats were divided into three groups. The first “irradiated” group comprised 21 pregnant rats that were injected intraperitoneally once on their 10th day of pregnancy with 1 ml of blood serum from an exposed Phase 1 donor rat. Rats in the second “sham exposure” group of 21 pregnant rats were similarly injected once on their 10th day of pregnancy, but with 1 ml of blood serum from unexposed Phase 1 donor rats. The third “biological control” group of 17 pregnant rats were not injected at all. Table 3 outlines the conditions in Phase 2 for each group of pregnant rats.

The reaction of the pregnant rats to the injection process was minimal. A reaction 1 hour after injection was observed only in one rat from the sham exposure group (4.8%) and in 3 rats (14.3%) from the irradiated group. These reactions lasted up to 1 hour. There were no deaths among pregnant test subjects and control females during the entire experiment.

Table 3. The distribution of rats for each experimental condition and timing of procedures

Group	Condition	N	Day of injection during pregnancy	Number and timing of rats sacrificed during pregnancy		
				Day 15	Day 20	Left to reproduce
1	Irradiated	21	10	5	4	12
2	Sham exposure	21	10	6	4	11
3	Biological control	17	-	6	-	11
Total		59		17	8	34

From each experimental group, 5-6 rats were sacrificed on their 15th day of pregnancy so as to assess embryonic death and foetal development features, while 4 rats were sacrificed on their 20th day of pregnancy so as to assess total intrauterine death. A further 11-12 pregnant rats were left until birthing for the purpose of subsequent monitoring of the development and survival of the offspring.

Fertility of rats. The fecundity of females calculated from the number of live foetuses on the 20th day of pregnancy and the number of live newborns in the group with sham exposure did not differ from the fecundity of control animals (8.1±0.7 and 8.2±1.1, respectively). In the group of rats treated with irradiated serum, this indicator was 3.2±1.1 and was statistically significantly lower with a probability of 99% ($p<0.01$) than in the females of the control group and the group with sham exposure shown in Table 4.

Table 4. Fertility of rats of different groups

Group	Total pregnant females	Scored on the 20th day of pregnancy			Births			Total number of newborns and live foetuses on the 20th day of pregnancy	Fertility	
		Total	No of live offspring	Total of live offspring	Total used	Birth No	%		Number of foetal females	Number of pups per female
With irradiated serum	16	4	3	30	12	4	33.3*	61	43.8	3.2±1.1*
Sham exposure	15	4	3	33	11	9	90.0	122	80	8.1±0.7
Control	11	-	-	-	11	11	100.0	90	100	8.2±1.1

* The significance of differences between the group with irradiated serum in relation to the control and the group with sham irradiation was 99% ($p<0.01$).

Offspring: the state of the offspring was studied from the newborn period until 30 days of life, using a number of generally accepted integral and specific indicators. Offspring weight and death were evaluated for their dynamics over time: first as newborns, then on their 7th, 14th, 21st and 30th days of life.

Weight of newborns: There were no differences in body weight in newborns in all three groups of females. The appearance of the rat's skin/coat, the detachment of the auricle, the opening of the eyes, the eruption of the incisors, and the onset of self-feeding were recorded. A total of 133 newborn offspring were monitored.

The death of the offspring of rats from birth to 30 days of life did not differ significantly from the death of the offspring in the group with sham exposure and in the control group (35,5±8,6%, 42,7±5,2; and 38.9±5.1, respectively).

Comparison of the total death of offspring during intrauterine and postnatal life shows a higher death of offspring in the group with irradiated serum with a very high probability of 99.9% ($p<0.001$) compared with the group with sham exposure and with the control group (Table 5).

Table 5. Total death of offspring during intrauterine and postnatal life (%)

Type of Death	Groups		
	Control M±m	Complex Exposure M±m	With irradiated serum M±m
Total intrauterine death, %	4.3±2.9	11.7±3.3	55.6±4.0*
Total postnatal death, %	38.9±5.1	42.7±5.2	35.5±8.6
Total, %	43.2±4.3	54.4±4.1	91.1±2.3*

* When comparing the death of embryos and the total death of embryos and offspring, the differences are statistically significant (p<0.001), both in comparison with the control and in comparison, with the group of sham exposure.

Dynamics of body weight of descendants: The body weight of the progeny of females irradiated serum were significantly lower than body mass of descendants of the control group and the group of females with a sham impact. The lag in body weight gain in the offspring of females with irradiated serum, compared with the offspring of the control group and the group with sham irradiation, was observed from day 14 and increased with age (in the period from 21 to 30 days, the reliability of differences increased and amounted to 99.9% (p<0.001). The maximum lag in growth was observed during the transition to self-feeding shown in Table 6.

Table 6. Dynamics of body weight of offspring of rats up to 30 days of life.

Observation period in days	Groups					
	Control		Sham Exposure		With irradiated serum	
	Number of descendants	Body weight, g M±m	Number of descendant s	Body weight, g M±m	Number of descendant s	Body weight, g M±m
Newborns	90	5.7±0.5	89	5.5±0.5	31	5.5±0.9
7	87	12.9±0.6	69	13.5±0.4	30	11.9±0.5
14	86	21.3±0.7	69	22.1±0,9	30	19.0±0,4*
21	68	33.6±0.9	65	29.6±0,7*	26	20.4±1,2**
28	57	53.3±1,2	51	58.6±1,6*	20	36.7±2,3**
30	55	63.1±2.2	51	66.5±1.8	20	47.5±3.4**
Coefficient of body weight gain by day 30		11.1±0.6		12.1±0.7		8.6±0.6*

* *differences between irritated and control/sham are statistically significant ($p<0.05$)*
** *differences between irritated and control/sham are statistically significant ($p<0.001$)*

Data on the formation of some other indicators of the development of descendants were not reliable.

Summarizing the results of studying the effect of RF-EMF of low intensity on the so-called teratogenic effects, it can be concluded that a single intraperitoneal administration to rats on day 10 of pregnancy, of serum from irradiated animals RF-EMF (30 days exposure for 7 hours per day with PD 500 μW/cm^2) had a negative impact on the embryonic development of fetus and offspring. In the group of females with irradiated serum, compared with the group of females with sham exposure and the control group, there was a higher embryonic death, a decrease in fertility, as well as a lag in the offspring's physical development.

The obtained results give us the right to draw a conclusion about the reproduction of previously obtained results (Shandala & Vinogradov, 1982), regarding the possible adverse effect of the serum of rats exposed to prolonged RF-EMF (30-day exposure to RF-EMF for 7 hours a day with a PD of 500 μW/cm^2) on the course of pregnancy, foetal development and offspring.

These results confirmed the validity of the use of previously obtained data to justify the RF-EMF standards in the USSR, which are still valid in Russia since 1984. Therefore, for the reason just outlined the immune system must be treated as a critical system for lifelong exposure of the body to low-intensity RF-EMF. In support of this decision are the also the bioeffects on the reproduction of previously obtained results by Shandala & Vinogradov, 1982, regarding the possible adverse effects of the serum of rats exposed to prolonged RF-EMF (30-day exposure to RF-EMF for 7 hours a day with a PD of 500 $\mu W/cm^2$) on the course of pregnancy, foetal development and offspring.

The results discussed earlier in Chapter 1 on the effects of MMW on immunity allow us to extend our view of the immune system as a critical system and important to any risk assessment regarding the use of 5G technology

Reproductive system

Reputable research organizations around the world have published numerous papers investigating possible links between *fertility* and the use of mobile phones. The Centre for Reproductive Science (University of Newcastle)—based in Callaghan, New South Wales, Australia—has performed a number of such studies and found detrimental effects on sperm. In fact, it has been consistently reported that those who use mobile phones regularly tend to have a decreased quantity and quality of sperm.

A survey of the literature shows that many human volunteer provocation studies have been conducted, as well as *in vivo* testing (animal experimentation). Over the past 5 years, there have also been many scientific reviews on changes to male fertility as a result of RF-EMF exposures. A review paper published by Vereshchako in 2015 provides a detailed analysis of results from more than fifteen (mainly foreign) studies carried out on human volunteers. Despite all this work, there is still no overall scientific consensus on the impact of cell phone RF-EMFs on the male reproductive system. Research into reproductive effects—similar to other areas of scientific inquiry into RF-EMF effects—shows varying results.

To review the possible effects of Wi-Fi exposures (2.45 GHz) on the animal and human male reproductive system, Jaffar et al. (2019) extracted data from 23 studies on rats, mice and human health. During animal testing, a structural and physiological analysis of testicles showed the development of degenerative changes, a decrease in testosterone levels, an increase in the number of apoptotic cells, and DNA damage. However, these effects were mainly associated with an increase in testicular temperature and oxidative stress.

A review by Kesari et al. (2018) focussed on *in vitro* and *in vivo* studies investigating the impact of RF-EMFs from cell phones, laptops, Wi-Fi and microwave ovens. The review showed that that this radiation clearly has deleterious effects on sperm parameters such as sperm count, morphology and motility; it affects the role of kinases in cellular metabolism and the endocrine system; and, it produces genotoxicity, genomic instability and oxidative stress. The authors concluded that "RF-EMF may induce oxidative stress with an increased level of reactive oxygen species, which may lead to infertility."

A review by Altun et al. evaluated the metabolomic effects of EMF exposure in the male and female reproductive systems (2018) and discussed possible mechanistic pathways for effects on fertilization, oogenesis and spermatogenesis. It reported that prolonged exposure to mobile phone EMFs reduces sperm motility and fertilization, and oxidative stress suppresses antioxidant mechanisms in germ cells.

A review by Houston et al. (2016) examined 27 publications that the authors identified as having investigated the impacts of RF-EMR on the male reproductive system while looking for insights into a potential mechanism for effects on sperm function. Negative effects of exposure were reported in 21 of the 27 studies. Of these 21 studies: 11 out of 15 that examined *sperm motility* reported a significant decline; 7 out of 7 that measured the production of *reactive oxygen species* confirmed the presence of elevated levels; 4 out of 5 studies that examined *DNA damage* revealed an increase in sperm damage. Overall, the sperm damage was characterized by a loss of sperm motility and viability, as well as an induction of ROS formation and DNA damage.

A review and meta-analysis of human *in vivo* and *in vitro* studies by Adams et al., 2014 concluded that the scientific evidence suggests that mobile phone exposure negatively impacts sperm quality. The indicators of sperm quality that are most often used to assess fertility in clinical settings are: *motility* (the ability to move correctly through the female reproductive tract), *viability* (the ability to fertilize an egg) and *concentration* (the number of spermatozoa per millilitre of ejaculate). These indicators were collated from ten different studies that included samples from 1492 mobile phone users. Mobile phone exposure was linked to *reduced sperm motility* (by an average of 8%) and *reduced viability* (by an average of 9%). The effect on sperm concentration was uncertain.

An *ex vivo*, *in vitro* study by Avendano et al. (2012) evaluated the effects of using an internet-connected laptop via a local Wi-Fi network on spermatozoa. This experimental human study was conducted in strict accordance with radiobiological ethical standards, and 29 semen samples were collected from healthy donors after their 2-5 days of sexual abstinence. For each of these samples, one half portion was exposed to an actively wifi-connected laptop, while the other half (the control) had identical environmental conditions, but without the presence of a laptop. The distance between the laptop and each sample was kept constant at 3 cm, which roughly corresponds with the distance between the testicles and a laptop when it is utilized on a user's lap. The RF-EMF irradiation from the laptop was 2.4 GHz Wi-Fi for 4 hours. Notably, the PD in this study was a maximum of 1.1 μW/cm^2., which was 7 or more times higher than background levels, and a thousand times lower than the current ICNIRP guidelines which allow for local exposures of 2000 μW/cm^2. Sperm motility, viability and DNA fragmentation were evaluated after exposures. There were no differences between the percentage of viable sperm in the experimental samples and the control samples. However, there was a significant decrease in sperm motility and a significant increase in DNA fragmentation for the exposed samples. The authors believe their findings suggest that prolonged use of wireless devices on the laps of male users may decrease male fertility.

Since young people often use EMF-producing devices, Simaiova et al. (2019) evaluated the effect of whole-body pulsed RF exposures (2.45 GHz with a mean PD of 2.8 mW/cm^2) on testicular structure and ultrastructure in juvenile Wistar rats. Four groups of rats were used, with each group comprising six rats. At the start of the experiment, the two control groups consisted of 14-day-old and 21-day-old rats respectively; likewise, the two experimental (or exposed) groups of rats were also 14 and 21 days old. Both of the "exposed" rat groups were irradiated for two hours per day, over three weeks. EMR exposure under the above conditions caused irregularly-shaped seminiferous tubules with desquamated (peeling off) immature germ cells in the lumen, a large number of empty spaces along the seminiferous epithelium and dilated and congested blood vessels in the interstitial testicular tissue. The cytoplasm of sertoli cells showed strong vacuolization and damaged organelles with the cytoplasm filled with various heterophagy and lipid vacuoles or the cytoplasm of spermatocytes with swollen mitochondria in both irradiated groups. A significant increase in the total tubular area of the seminiferous tubules was observed in both EMR-exposed groups compared to the controls ($p<0.001$). A significant increase in TUNEL-positive apoptotic nuclei ($p<0.01$) was accompanied by a significant rise in both Cu-Zn-SOD ($p<0.01$) and Mn-SOD positive cells ($p<0.001$) in the 6-week-old experimental rats compared to the control animals. The authors concluded that their results serve to confirm that exposure to RF-EMF under these experimental conditions has a harmful effect on the structure and ultrastructure of the young rat testis.

The experimental work of Oh et al., (2018) is noteworthy because it investigated effects on rat spermatogenesis from *long-term*, full-body exposures to EMFs by a 4G-LTE mobile phone. The authors wanted to investigate how spermatogenesis effects are influenced by two factors: the *distance* from the RF-EMF exposure, and the *duration* of the exposure. Twenty adult rats were randomly assigned to four groups for differing exposure intensities and durations as follows: Group 1 was the *sham exposure* (control group); Group 2 was irradiated at a distance of *3 cm for 6 hours daily*; Group 3 was irradiated at a distance of *10 cm for 18 hours daily*; and Group 4 was irradiated at a *3 cm distance for 18 hours per day*. All three exposure groups were irradiated for a period of 28 days. Semen analysis was then performed in two stages. Firstly, the average number of spermatids was counted, showing a significantly lower number in group 4 than in group 1. Group 4 ($p = 0.041$). For the second review, the average number of spermatogonia in experimental Group 4 was was found to be significantly lower than both control Group 1 $p<.001$)) and Group 2 ($p =0.01$).. The Leydig cell count decreased with the increasing exposures of Groups 1 to 4, and therein the number of germ cells were fewer in l Group 4 compared to Groups 1, 2 and 3 ($p<0.001$). Overall, the longest daily exposure time more harmful effects.
These experimental results allowed the authors to make a rather important conclusion—that cell phone exposure is hazardous to spermatogenesis.

Kamali et al. (2017) investigated the effects of 3G + Wi-Fi modems on human sperm quality. From March to September in 2015, 40 semen samples were collected from healthy adult males. The semen samples were subject to either a sham control condition or an experimental exposure condition. In the exposure condition, the 3G modem was connected to a laptop computer which downloaded for 50 minutes. Two of the four categories of motility indicators for spermatozoa showed significant average changes: one was significantly lower in the irradiated group (p=0.046), and the other was significantly higher (p=0.022). Velocity curvature, velocity straight, mean velocity path, mean angular displacement, transverse displacement, and transverse beat rate were significantly higher in the non-exposed group. This study reveals that EMR emitted by 3G + Wi-Fi modems can cause a significant decrease in sperm motility and velocity, especially in non-progressive motile sperm. as well as a decrease in the quality of human sperm.

Over the past six years, more than 20 papers have reported on human studies or laboratory animal experiments regarding the effects of RF-EMF on fertility and spermatogenesis. The results of all these studies confirm our conclusion that there is an adverse effect from this type of radiation that may affect fertility (Adams et al., 2014; Agarwal et al., 2007, 2008; Akdag et al., 2016; Al-Bayyari et al., 2017; Al-Quzwini et al., 2016; Houston et al., 2016, 2018; Kamali et al., 2017;; Liu et al., 2014; Narayanan et al., 2018; Oyewopo et al., 2017; Pandey et al., 2016; Radwan et al., 2016; Saygin et al., 2015; Sepehrimanesh, Kazemipour et al. 2017; Seperhimanesh & Davis et al., 2017; Sokolovic et al., 2015; Solek et al., 2017; Wang et al., 2015; Zang et al., 2016).

National Academy of Sciences Belarus large rat studies

We would like to draw attention to research work completed by the *Institute of Radiobiology* of the *National Academy of Sciences*—a state scientific institution in Gomel, Belarus—from 2011 to 2020. Over the last three years of this period, a comprehensive series of experimental studies was conducted to assess morphological and functional (morphofunctional) changes in the reproductive system under the influence of low-intensity EMR. Different durations of mobile phone exposures at frequencies of 897 MHz and 1745 MHz, with an average PD of 5 ± 0.34 μW/cm^2 were used at the *prenatal* and *postnatal* stages of rat development (Vereshchako, Chueshova et al., 2014; Vereshchako & Chueshova, 2017; Grigoriev, Chueshova & Vereshchako, 2018; Chueshova & Vismont, 2019; Chueshova, Novikov, Kozlov et al., 2019). Chueshova's research was included in the top ten achievements of scientists at the National Academy of Sciences of Belarus for 2019. This large-scale series of experiments (utilizing 2000 white rats) was conducted in three phases, which we describe below (Chueshova, 2019).

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Phase 1: Animal reproductive systems undergo significant changes in the period between the animal's birth and its sexual maturity. In this regard, in the first part of these animal experiments, rats were exposed to mobile phone radiation at frequencies of 897 and 1745 MHz from days 50 to 52 of the rats' lives, until they reached the age of 140-142 days. A comprehensive analysis of the state of sperm in the male rats was performed on exposure days 1, 7, 30, 60 and 90.

Results of phase 1: The results showed that the nature of the morphofunctional changes identified in the reproductive system of male rats exposed to low-intensity EMR from mobile phones largely depends on the *duration of exposure* and the *age* of the animals. Thus, the impact of EMR from mobile phones on the body of male rats at the phase of their *puberty* leads to the most significant changes in the developing reproductive system. The mass of epididymis and seminal vesicles increases. Changes in the process of spermatogenesis develop, which are manifested by an inhibition of proliferative activity (a decrease in the number of spermatogonia) and activation of differentiation of spermatogenic epithelial cells (spermatids), accompanied by a significant increase in the number of epididymal spermatozoa (early puberty), with a decrease in their viability against the background of a decrease in the concentration of testosterone in the blood serum. Disruption of the synthesis of steroid hormones, as well as some neurotransmitters was established, which can be explained by the sensitivity of the receptors of the hypothalamic-pituitary-testicular axis from prolonged exposure to low-intensity EMR from mobile phones.

Phase 2: The second series of experiments focused on studying effects of chronic EMR on the *fertility* and *morphofunctional state of male sperm* in rats in the first generation (F1) after chronic mobile phone irradiation at a frequency of 897 MHz, and, in three generations (F1-F3) after chronic mobile phone irradiation at a frequency of 1745 MHz.

Results of phase 2: Chronic irradiation of male and female rats during their prenatal and postnatal periods (by mobile phone EMR for 8 hours per day) over three generations, leads to a *drop in the birth rate of animals* and a *change in the sex ratio* towards an increased proportion of males. Male rats of the resulting F1-3 offspring at the age of 2, 4 and 6 months showed *changes in the state of the reproductive system*—the most significant being at the age of 2 months.

Phase 3: This third stage of research aimed to study the effects of mobile phone EMR exposures (1745 MHz) on the morphofunctional state of sperm in the *male offspring* of rats from the first phase of the experiments - at the age of 2 and 4 months[6] of the said offspring. (The *parents* of these rats had been exposed to EMR for three months from the age of 50-52 days.) The levels of testosterone and corticosterone in the blood serum were determined. Neurotransmitters were analyzed in the hypothalamic tissue. In a cell suspension obtained from testicular tissue, a quantitative analysis of various types of spermatogenic cells was performed by flow cytometry. The number of epididymal spermatozoa, their viability and the number of apoptotic forms were counted.

Results of phase 3: The results of this phase enabled the authors to make the unique observation that exposure to RF-EMR can cause long-term (trans-generational) changes in the morphofunctional state of the sperm of male rats born from parents exposed to RF-EMR during their postnatal development. These changes are manifested in a violation of the normal functioning of the spermatogenic epithelium, namely, there was an intensification of the initial stage of spermatogenesis, with its significant inhibition at the stage of spermatid transformation. A decrease in the number of mature germ cells

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[6] This age is said to correspond roughly with early adulthood in humans.

(or spermatozoa) and a marked deterioration in their viability, as well as an increase in testosterone secretion were found.

The array of disorders that are found in the morphofunctional state of the sperm of male rats indicates the inhibition of its function when it has been exposed to low-intensity EMR from mobile phones. This EMR exposure can induce a decrease in male fertility. The disruptions observed are dependent on the duration of exposure and the age at which the animals are exposed.

Based on the many scientific findings we have described above; we conclude that the reproductive organs are critically vulnerable to EMR exposures.
The dose of radiation that is absorbed by the reproductive organs, and, consequently, the severity of the pathology of the reproductive system is directly affected by the location of the devices that are being used.

Long-term consequences: brain and thyroid tumors

When assessing the risk to human health from exposure to physical environmental factors, the traditional radiobiological school of thought in Russia, is to favour the impact of *long-term consequences*. In our opinion, thus far, the only clear and incontestable criterion available for evaluating potential health impacts for the public from RF-EMFs, is the evidence of the development of brain and thyroid tumors in mobile phone users. This is now further enhanced by the fact that these rare nerve tumors (vestibular schwannomas) were found in the hearts of rats as a result of the US $30 million NTP 2018 animal study (Hardell and Carlberg, 2019)

Brain Tumors

With regard to *brain tumors*: in May 2011, the International Agency for Research on Cancer (IARC) of the World Health Organization (WHO), identified RF-EMFs as a "Group 2B" carcinogenic agent— thus placing it in the category of being "*possibly* carcinogenic to humans". This classification was largely based on the results of mobile phone epidemiological studies which indicated that there was an increased risk for glioma—a highly malignant type of brain cancer. The IARC highlighted the particular relevance of this classification for *mobile phone users* in their press release, stating that, since the number of users is large and growing—notably among young adults and children—it could have a significant impact on public health (International Agency for Research on Cancer 2011).

The press release stated that a past study of cell phone us - up to the year 2004—had shown that the risk of developing a glioma (a type of brain tumor) could increase by up to 40% in the "heavy user" category. In this study a "heavy user" was someone who, on average, used a mobile phone for 30 minutes a day, for more than 10 years. The Working Group that made this decision was composed of 31 scientists from 14 countries. In the following month, the IARC published a report summarizing the main conclusions of the Working Group, and their evaluations of radiofrequency electromagnetic fields as a carcinogenic hazard (IARC, 2011).

In 2011 and 2012, however, at meetings of the WHO's *International Advisory Committee* for the *International EMF Project*, a majority of the members actively promulgated the notion that the IARC's conclusion in classifying this agent as a carcinogen was unjustified, as there had been insufficient data available.

Nonetheless, a group of Swedish scientists, led by Hardell, conducted a series of epidemiological studies (2013, 2015) on the development of brain tumors (malignant gliomas and acoustic neuromas) in mobile phone users over the course of more than 15 years. They found that mobile phone users had an *increased risk* of developing brain tumors when using mobile and cordless phones. There was an increased risk of developing gliomas and acoustic neuromas (also known as a vestibular schwannoma) on the ipsilateral side of the brain—this means that the risk of a brain tumor was found to be higher on the same side of the head that the mobile phone was used. The risk of glioma was greater in people who began using a mobile phone before the age of 20. The development of the tumor was found to be dependent on the duration of mobile phone use.

Professor Lennart Hardell MD, PhD is a Swedish oncologist and cancer epidemiologist at Örebro University Hospital. In his long career as a clinical and medical research doctor, he has focused on environmental risk factors for cancer.

In 2015, a statistical summary published by the *Central Brain Tumor Registry of the United States* (CBTRUS) - depicted the epidemiological data on primary brain and central nervous system (CNS) tumors for the diagnosis years 2008-2012. This summary was based on the materials of the Center for Disease Control and Prevention (CDC), the National Program of Cancer Registries (NPCR), and the National Cancer Institute's (NCI) *Surveillance, Epidemiology and End Results* (SEER) program. An increased incidence of brain and CNS tumors was found in various age groups of the US population between the years 2000 and 2012 (CBTRUS, Statistical Report, 2015).

Philips et al. (2018) investigated the trends of malignant brain tumor incidences in England between 1995 and 2015. They analyzed data from the UK's *Office for National Statistics* (ONS) and calculated the incidence rates of brain cancer in the population. The study found a sustained and highly statistically significant increase in the incidence of glioblastoma multiforme (GBM) for all ages. The finding was particularly notable for the frontal and temporal lobes. The incidence of GBM had doubled from 2.4 to 5.0 cases per 100,000 people. In 1995, the percentage of total malignant tumors of the frontal or temporal lobes of the brain was 41%, but by 2015, 60% of the brain tumors were identified as being GBM tumors. The report concluded: *We suggest that widespread* *environmental or lifestyle factors may be responsible, although these results do not provide additional evidence for the role of any particular risk factor.*

A 2020 comprehensive review of epidemiological studies (meta-analysis) on the association between *cell phone use* and *tumor risk* (Choi et al.) identified that using a cell phone, with a cumulative talk-time of more than 1,000 hours, significantly increased the risk of tumors:

> *In sum, the updated comprehensive meta-analysis of case-control studies found significant evidence linking cellular phone use to increased tumor risk, especially among cell phone users with cumulative cell phone use of 1000 or more hours in their lifetime (which corresponds to about 17 min per day over 10 years), and especially among studies that employed high quality methods.* (Choi et al., 2020)

Despite the evidence of published longitudinal epidemiological studies, classical radiobiological *animal experiments* are nonetheless an important corroboration of the pathological development of tumors.

The *National Toxicology Program* (NTP) is an interagency program run by the United States *Department of Health and Human Services* (HHS), and headquartered at the *National Institute of Environmental Health Sciences* (NIEHS). In 2016, the NTP released early draft findings of their $30 million series of experiments investigating the potential health hazards of cell phone RFR exposures. This study reported finding "clear evidence" of carcinogenesis from exposures to CDMA and GSM RFR-EMFs (Wyde, 2016). The early release of partial study data in 2016 was prompted by the "widespread global usage of mobile communications among users of all ages, [since] even a very small increase in the incidence of disease resulting from exposure to RFR could have broad implications for public health" (Wyde et al. 2018). The two-year toxicology study of rats and mice was conducted on behalf of the FDA with the aim of exploring potential long-term health problems from *whole-body*, *non-thermal* RFR exposures from cell phones (National Toxicology Program website, US Department of Health and Human Services, 2021).

The rats in the experiments were allowed to roam freely in their cages; they were irradiated by 900 MHz RFR frequencies (with the GSM and CDMA exposure standard modulations) at 10-minute intervals, for 18 hours a day - from gestation day 5 until weaning at postnatal day 21, and then for a further two years. There were four groups of rats, each consisting of 90 male and 90 female pups. One group was the *control* group, with sham irradiation; the other three groups were irradiated at *non-thermal* intensities of SARs 1.5 W/kg, 3 W/kg and 6 W/kg, so as to exclude the so-called "thermal effect".

The results showed clear evidence of carcinogenic activity among experimental rats over the two years of exposure. There was *clear* evidence of tumors in the hearts of male rats (malignant schwannomas); s*ome* evidence of tumors in the brains of male rats (malignant gliomas); and *some* evidence of tumors in the adrenal glands of male rats (benign, malignant, or complex combined pheochromocytoma). All the data for these studies is freely available at the NTP website. A detailed review of interim genotoxicity evaluations of additional animals after a shorter 14-week (or subchronic) exposure was published later (Smith-Roe et al., 2020). The results suggested that exposure to RF-EMF is associated with an increase in DNA damage. This conclusion contradicts the ICNIRP guidelines, which recommend an allowable exposure level for mobile phones at a SAR dose of 2.0 W/kg.

The results of this unique two-year classical radiobiological experiment strengthened the IARC's previous assessment of RF-EMFs as being a potential danger to human health. This experimental evidence added credence to the previous epidemiological conclusions that the development of brain tumors was a possibility. Consequently, it also confirms that there is a significant risk to the health of mobile phone users.

Later in the same year, the results of another important radiobiological animal experiment (Falcioni et. al., 2018) conducted by the Ramazzini Institute in Italy - were published. It is worth noting that the Ramazzini Institute has been studying the toxic effects of chemicals and other physical factors (including RF-EMF) for decades.

The €15 million Ramazzini experiment was a *far-field* animal experiment using weaker power densities, while the NTP study had involved (closer) whole-body exposures to the rats with a much higher power density. The new Italian Ramazzini study represents human RF-EMF exposures that resemble the far-field exposures experienced by the general public today in the vicinity of local *base stations*, while the US NTP exposures were more applicable to the close-up exposures experienced from *cell phones*. Exposure levels for the Ramazzini experiment were *within* the current ICNIRP guidelines for far-field exposures to the general public. Despite these different types of exposures in the two studies, the finding of schwannoma tumors in the hearts of rats was a consistent outcome.

The massive Ramazzini Institute experiment used 2448 male and female rats. The animals were exposed to a 1.8 GHz GSM signal for 19 hours a day from gestation Day 12, until their natural death. SAR values ranged from 0.001 W/kg to 0.1 W/kg, compared to the 1.5 to 6.0 W/kg of the NTP experiment. Irradiation levels in the Italian experiment were within the current ICNIRP limits for brain exposures (2.0 W/kg).

The results showed that long-term cell phone use is associated with an increased risk of developing vestibular schwannoma cancer in the heart. An increase of the incidence of malignant glial tumors in female rats was also found, although it was not statistically significant (Falcioni et al., 2018).

Despite the different levels of exposure, both the Rammazini and the NTP studies revealed a statistically significant increase in risk for developing the same type of tumors (schwannoma) in the heart in male rats. Heart schwannomas are usually a rare nerve tumor in humans, however acoustic neuromas (in the brain) have been linked to cell phone use before (Hardell (2013). Acoustic neuromas also originate from Schwann cells, but unlike their counterpart in the heart, are usually slower-growing benign tumors. The Ramazzini study concluded:

> *The RI findings on far field exposure to RFR are consistent with and reinforce the results of the NTP study on near field exposure, as both reported an increase in the incidence of tumors of the brain and heart in RFR-exposed Sprague-Dawley rats. These tumors are of the same histotype of those observed in some epidemiological studies on cell phone users. These experimental studies provide sufficient evidence to call for the re-evaluation of IARC conclusions regarding the carcinogenic potential of RFR in humans.* (Falcioni et al., 2018)

In our view, it is fundamentally important that, in this experiment, the development of brain tumors was found at the same RF-EMF radiation intensities of base stations.

It is notable that the adverse outcomes of both of these experiments occurred within the power density levels recommended by ICNIRP for whole body exposures.

The conditions of exposure in these two experiments can be equated with real-life RFR-EMF exposures that the general public are exposed to from wireless communications sources that provide internet services; for example, base stations, Wi-Fi and cell phones.

Earlier animal studies have provided evidence that non-Hodgkin's lymphoma can be caused by exposure to RF-EMF (Swedish Non-Hodgkin's Lymphoma Registry). Primary central nervous system (CNS) lymphoma is a rare malignant disease in humans and with a poor prognosis. In recent years, there has been an increase in morbidity. Based on the NTP report and the Swedish Registry, Hardell L. et al. (2020) concluded that the use of mobile phones may be a risk factor for the CNS. Non-Hodgkin's lymphoma (NHL) is a common cancer among patients with suppressed immune systems. This paper discusses the case of a very heavy mobile phone user (13,200 cumulative hours over a 15-year period). This equates to approximately 4 hours per day of head/brain radiation and this tumor was located on the same side of the head as the user's handedness.

After completing these two major studies, the National Toxicology Program in the United States and the Ramazzini Institute in Italy many scientists believe that there is now "clear evidence" that radiation exposure to a cell phone can cause brain cancer. Hardell. in 2018, considered these results of these two experiments, proposed to modernize the IARC classification and transfer R- EMF to be now redesignated this radiation as Group 1, "as a real carcinogen for the population". Russian scientists agree with this decision (Samoylov, Grigoriev, 2020).

The USA Food and Drugs Admission (FDA) who are responsible the management on sanitary inspection behind quality of foodstuff and medicines of the USA reacted in an unusual manner. The FDA quickly issued a statement questioning the findings in the NTP report and stating that "Animal studies like this make it necessary for us to discuss this topic. We must remember that the study was not designed to test the safety of cell phone use in humans, so we cannot draw conclusions about the risks of cell phone use from this experiment."

The results of long-term epidemiological studies (Sweden, USA, UK), conducted radiobiological experiments in the USA under the NTP program and the results obtained by the Ramazzini Institute, as well as the IARC decision, allow us to believe that the development of brain tumors in the long-term period is a reliable criterion for assessing the danger of EMF in cellular communication. However, the development of this carcinogenesis is problematic to be influenced by additional exposure to MMW (5G), although we can expect the development of a wider range of skin tumor processes in these conditions.

Thyroid tumors

The incidence of thyroid cancer (thyroid) is increasing in many countries, especially papillary cancer type carcinomas. A number of scientists associate this effect with the effect of mobile RF-EMF on the thyroid gland. In 2014, data were published that suggest an increase in the incidence of thyroid cancer in South Korea since 2002 (Ahn et al., 2014). The corresponding dynamics of the "epidemic" of thyroid cancer as shown in Figure 18.

The authors point out that according to the Agency for Research on Thyroid Cancer, diseases have more than doubled in France, Italy, Croatia, the Czech Republic, Israel, China, Australia, Canada and the United States, but without a corresponding increase in mortality. The authors of this work believe that this is only the "tip of the iceberg" of thyroid cancer.

In 2017 and 2018, two generalizations were also made about the growth of thyroid papillary tumors associated with intense EMF exposure (Lim, 2017; Luo et al., 2018).

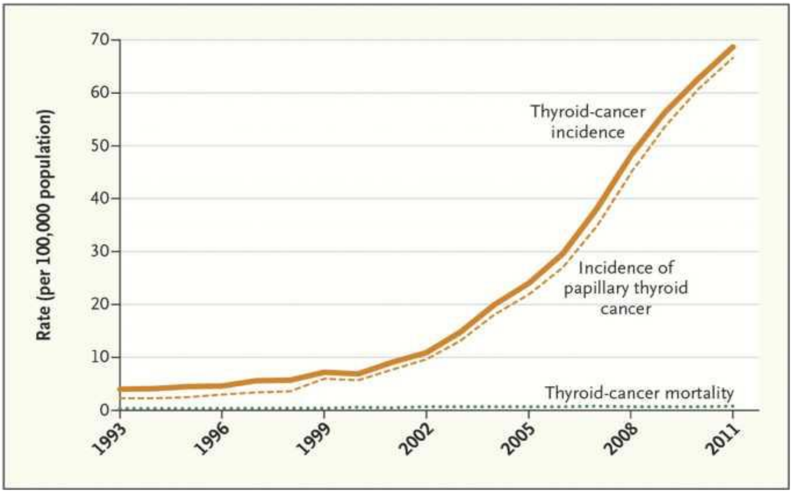

Figure 18: Dynamics of thyroid cancer incidence in South Korea (Ahn H. et al., 2014)

The incidence of papillary thyroid cancer and mortality among patients in the United States increased from 1974 to 2013, and its annual percentage, on average, was 4.4%. Mortality between 1994 and 2013, based on the incidence of thyroid cancer, increased by 1.1% per year.

Previous studies on the association between mobile [phone use and the development of thyroid cancer in the United States were summarized by Luo et al (2018). This research was conducted by the Yale School of Medicine and the Connecticut Department of Health, USA. The authors predicted that high risk, “heavy” users (talking on the phone for more than two hours a day) and long-term users of mobile phones (more than 15 years) are likely to have a very high risk of addiction. Furthermore, women who used mobile phones for more than two hours a day had a higher risk of developing thyroid cancer compared to cordless phones.

Thyroid cancer is the fastest growing disease in the United States: its frequency has increased almost three times. In the 1980’s there were 4 cases per 100,000, in 2014 this had risen to 15 cases per 100,000. The increase in new cases of thyroid cancer has increased to an average of 3% per year over the past ten years, according to the NCI

Surveillance. Epidemiological results from the USA Surveillance, Epidemiology and Results-9 (SEER-9) and the U.S. National Cancer Institute's Thyroid Cancer Registry (see Figure 19). The registry estimates that 53,990 new cases of thyroid cancer were diagnosed in 2018, making it the twelfth most common disease in the United States.

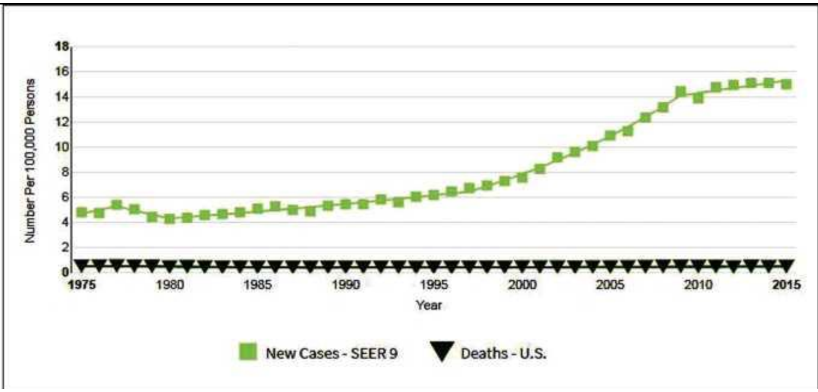

Figure 19: Dynamics of thyroid cancer development and mortality in the U.S.

The analysis of the published results allows us to state that electromagnetic fields can lead to a high risk of hyperthyroidism or carcinogenesis, inducing changes at the level of the entire body.

Timely individual monitoring will allow you to identify and evaluate the changes in the thyroid gland. This dictates the need for more extensive and regular medical monitoring and the use of modern methods for early detection of thyroid disorders and cancer. This problem requires further comprehensive research (Grigoriev, Vorontsova, Ushakov, 2020).

Given the high sensitivity of the thyroid gland to physical factors, it is possible to develop adverse long-term consequences in the thyroid gland with lifelong exposure to MMW.

Children's bodies: vulnerability to EMF

WHO has defined its view on children's susceptibility to environmental factors: *Children are different from adults. Children have a unique vulnerability as they grow and develop; there are 'windows of receptivity': periods when their organs and systems may become particularly sensitive to the effects of certain environmental threats* (WHO backgrounder No. 3, 2003). Subsequent publications draw similar conclusions about the different radio-sensitivity between children and adult mobile phone users.

Unfortunately, the WHO Advisory Committee on the International Programme "EMF Risk Assessment for the Population" does not focus on this important postulate about the high radio-sensitivity of children to EMF. Against the background of the results of numerous studies indicating changes in the brain of users. Mobile phone use by children is not restricted. Attempts by the telecommunications industry to assert that mobile communication cannot have a negative impact on children look immoral as profits are placed ahead of health. The active promotion of measures for the safe use of mobile phones is hindered by the presence of the financial lobby of this industry associated with the introduction of cellular communications, which promotes the concept of complete safety for all groups of the population of EMF cellular communications, especially for children. Even the Mobile Manufacturers Forum (MMF) of this lobby is organized. The Foundation finances only research where the desired outcome of the research is a high probability of a "No Effect" study. For example, MMF published a special brochure entitled "MMF Industrial Forum, a point of view on the problem - mobile phones and children" (Viewpoint, mobile phones and children ..., 2008. According to this Committee, there is a strong scientific basis for all consumers, instilling confidence in the safety of mobile phones. It is impossible to formulate a more absurd conclusion, especially since there is no such scientific basis, and adequate experimental studies in the conditions of chronic exposure to RF-EMF on the developing brain of a child have not yet been conducted.

The current situation under the wing of the telecommunications industry lobby hinders research on the health effects and, in our opinion, purposefully translates the practical solution to the problem of electromagnetic safety into the mainstream of constant discussions. There are facts of unpunished concealment of the adverse effects of EMF cellular communication on children and, above all, on the part of the lobby of the telecommunications industry.

In Russia, the penalty for concealment of information given to teachers by educational officials about the danger to health of participants within educational systems is given in article 237 of the criminal code “Concealment of information on circumstances creating danger to life or health” where the directive is clear that:

> *Officials of educational organizations are obliged to report this threat to the public, as well as immediately take response measures to eliminate the danger to participants in the educational process.*

This is the first time in the entire period of civilization, there is a massive constant electromagnetic irradiation of the brain of a child/teenager and, first of all, the nerve structures of the inner ear and vital centres of the brain. With the support of parents, the child became the owner of a mobile phone, which is an open, uncontrolled source of EMF.

Despite the large number of publications on the effects of RF-EMF of mobile phones on the human body, estimates of the danger of this type of radiation on the body of children and adolescents are few and are based in most cases on epidemiological data obtained using questionnaires. The results of these studies indicate violations of the psychosomatic health of young users: increased levels of fatigue, aggressiveness, anxiety, hostility and social stress, reduced levels of resistance to stress (Van den Bulck, 2007; Inyang, Benke, Dimitriadis et al., 2010; Inyang, Benke, McKenzie et al., 2010). However, given that these studies are conducted remotely and by filling out questionnaires by parents themselves, there are serious questions about the reliability of the results obtained.

Evidence from rodent studies

The experiments that have been carried out on young mice and rats, performed only in the last few years, deserve attention. These experiments highlight the potential risks of EMF exposures for the brain of children and adolescents.

Narayanan, Kumar, Kedage et al. (2014) consider it possible to develop oxidative stress and antioxidant protection in discrete brain regions of adolescent rats exposed to 900 MHz EMF at levels of thiobarbituric acids (TBARS), total antioxidants (TA), and Glutathione S-Transferase (GST). Thirty-six male Wister rats aged 6-8 weeks were divided by a randomized sample into three groups of 12 animals in each group. Group (1) was the control group. Group (2) was the sham-control, the mobile phone present were shut down for four weeks of the experiment. Group (3) was the experimental group and were exposed to GSM mobile phone radiation for 1 hour per day with a peak power density of 146 $\mu W/cm^2$ from the active global mobile communication system (GSM). The switched-on mobile phone was in silent mode for four weeks, with no sound signal and no vibration. On day 29, behavioral responses were evaluated and then six animals from each group were decapitated and biochemical studies were performed in the amygdala, hippocampus, frontal cortex, and cerebellum. The authors noted changes in the behavior of irradiated animals. Increased levels of TBARS were found in all the brain structures studied, TA decreased in the amygdala and cerebellum, but in other areas of the brain, its level did not change significantly. GST activity decreased significantly in the hippocampus. In this paper, it is concluded that exposure to RF-EMF for a month induces oxidative stress in the brain of rats, but its magnitude differs in different studied brain structures. The development of oxidative stress may be one of the main causes of behavioral disorders in rats after exposure to RF-EMR.

Data on the adverse effect of the 900 MHz electromagnetic field on the hippocampus of 60-day on old adolescent male rats were obtained (Kriol, Hance, Bag et al., 2016). The hippocampus is important for functions such as memory acquisition, integration, and spatial memory. This study shows that EMFs can lead to serious damage in the hippocampus, both morphologically and functionally. The authors examined the hippocampus in 60-day-old male rats after exposure to 900 MHz EMF throughout adolescence, using stereological, histological, and biochemical analysis methods. Eighteen male Sprague Dawley rats at the age of 21 days were selected in the general control, sham - control and experimental. The EMF exposed groups were randomly selected to avoid basis. Rats in the RF exposed experimental group were exposed to EMF for 1 hour per day from the beginning to the end of adolescence. All rats were scarified at the age of 60 days. The left hemispheres of the brain were isolated for biochemical analyses, and stereological and histological assessments were performed on the right hemispheres. Histopathological studies have shown an increase in the number of pyknotic neurons (the cell nucleus becomes dense and compact and begins to fragment), with black or dark blue cytoplasm stained with cresyl violet. Stereological analysis showed a smaller number of pyramidal neurons in the experimental group than in the other two control groups. There was an increase in the levels of malondialdehyde and glutathione, a decrease in the level of catalase in the brain of irradiated rats. The results indicate that oxidative stress associated with morphological damage and pyramidal loss of neurons may be observed in the hippocampus of rats after exposure to 900 MHz RF-EMF throughout adolescence.

Possible pathological changes in the cerebellum were investigated in adolescent rats exposed to 900 MHz EMF daily for 25 days (Aslan, Ikinci, Bag et al., 2017). Three groups of six 21-day-old male rats were used: the general control group (OK EG), the deceptive group (Sham-K), and the EMF irradiated group (EMF - EG). Rats of the exposed experiment group were exposed to EMF for 1 hour daily from 21 to 46 postpartum days. The cerebellum of all animals was removed on postpartum day 47. Sections were stained with cresyl violet for histopathological and stereological analyses. Significantly fewer Purkinje cells were found in the EMF-experience EG group than in the OK EG and Sham-K groups. Histopathological evaluation revealed changes in the normal location of Purkinje cells (the cell nucleus becomes dense and compact and begins to fragment) and pathological changes, including intensive staining of the cytoplasm of neurons only in the experimental group. The authors found that exposure to continuous 900 MHz EMF for 1 h / day in adolescence can disrupt cerebellar morphology and reduce the number of Purkinje cells in adolescent rats.

Steinberg et al. (2000) obtained a significant increase in the number of grooming reactions in young rats compared to adult animals under the influence of complex signal EMF, at very low exposure levels. Animals were irradiated with EMF 4,200 and 970 MHz with a power density of 15 $\mu W/cm^2$ for 30 minutes. The results showed that young animals were more radiosensitive when exposed to RF-EMF with a complex signal.

Evidence from human studies

Noteworthy are the results of observations of Vyatleva and Kurgansky (2019) for school children aged 6-15 years for three years. A survey of 2,137 Russian school children aged 6-15 years (2008-2010) on the parameters of mobile phone use and health indicators (the frequency of headaches and sleep disorders, the number of colds per year) allowed the authors to identify age-critical modes of mobile phone use associated with the risks of frequent (several times a week) complaints about well-being. In children aged 6-10 years, the daily number of conversations >2 minutes and their total duration >6 minutes was associated with the transition to the group to the category of frequently ill people. Adolescents aged 11-13 years, who talk on the phone 6 or more times a day, increased the frequency of headaches. Adolescents aged 14-15 years with a daily number of conversations >6 and their total duration >10 minutes increased the risk of frequent complaints of headaches and sleep disorders.

In a more detailed study of 125 primary school children in Moscow, conducted in 2017-2019, the authors determined the radiation levels of individual mobile phone use, the electromagnetic load associated with their use, as well as the influence of mobile communication parameters on a wider range of health indicators and electroencephalogram (Vyatleva & Kurgansky, 2018). Measurement of power density from mobile phones at the user's head showed that its values vary from 0.1 to 300 μW/cm^2 and in 43.5% of children they exceed the standard for adults (100 μW/cm^2, SanPiN 2.1.8/2.2.4.1190-03). However, the high level of radiation was typical for older models of mobile phones with a push-button keyboard.

Using the formula developed by the authors for the approximate assessment of the daily electromagnetic load associated with the use of mobile phones, it was shown that in individual children its maximum values (273.4 μW/cm^2) are comparable to the maximum values for personnel of radio engineering facilities (200 μW/cm^2, SanPiN 2.1.8/2.2.4.1383-03).

When analyzing complaints about well-being in 80 children aged 7-10 years without a history of neurological complications, a positive correlation was found between the frequency of complaints about headaches, dizziness, anxiety and depression with the level of radiation and the use of mobile phones. The risk of vertigo was increased in children who used mobile phones with a maximum power density of >100 μW/cm^2 (OR 4.44; 95% CI 1,159. 27), talked on mobile phone daily for >6 minutes (OR 8.55; 95% CI 1.74-7.11) and had a daily electromagnetic load of more than 3.62 μW/cm^2 (OR 5.25; 95% CI 1.33-10.05). Children who spoke on a mobile phone for more than 2 times a day were at an increased risk of frequent (several times a week) complaints of anxiety. The use of mobile phone with a push-button keyboard (in comparison with smartphones) was associated with the risk of frequent complaints of depression (Vyatleva & Kurgansky, 2019).

An analysis of changes in the electroencephalogram after a single exposure to radiation in 13 children aged 6-13 years showed that a 3-minute exposure with a maximum power density of about 100 μW/cm^2 caused an extensive decrease in the power of the alpha rhythm, which was more pronounced in the ipsilateral hemisphere (Vyatleva, Teksheva & Kurgansky, 2016). According to the authors, there was an inhibition of paroxysmal activity of stem origin (Vyatleva & Kurgansky, 2017). The EEG effect of radiation with an exposed power density of less than 1 μW/cm^2 in the whole group no effect was obtained. Only in children younger than 10 years was there a different reaction from the placebo, in the form of local suppression of the alpha rhythm in the temporal cortex of the ipsilateral hemisphere (Vyatleva, Teksheva & Kurgansky, 2016). This differs from the results of previous repeated studies conducted by Lukyanova (2015).

Electrophysiological studies were conducted on children with different levels of daily electromagnetic load as measured by exposed power density (Vyatleva & Kurgansky, 2019; Vyatleva, 2019).

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The nature of bioelectric changes was different in children with an average load level (from 0.31 to 12.86 μW/cm^2) compared to peers with a low load (<0.31 μW/cm^2). At high-power density levels of load (>12.86 μW/cm^2), EEG changes (increased beta wave power) were more local and were observed in the frontal-central temporal zone of the right hemisphere, which is most often exposed to mobile phones. In children with a higher daily load and overall duration of mobile phone use, there was also a change in the interhemispheric asymmetry of the alpha rhythm in the form of its amplification in the hemisphere, which is most often exposed to mobile phone radiation.

In Russia, Khorseva and Grigoriev have been conducting long-term (longitudinal) psychophysiological studies of school children and mobile phone users since 2006. In contrast to foreign epidemiological studies using questionnaire remote and insufficiently objective methods, this work evaluates the reactions of the central nervous system of children and adolescents to electromagnetic radiation of mobile phone using psychophysiological tests, having direct constant contact with the child and parents. This is the only “direct contact” long-term study of the chronic effects of electromagnetic radiation from mobile phones on the body of children and adolescents. The organization of monitoring studies is described in detail in the book by Yu. G. Grigoriev and Khorseva (2014).

The results obtained indicate a possible adverse effect of mobile phone radiation on the nervous system of children and adolescents. The following factors were established: increased response time to sound and light signals, impaired phonemic perception, decreased working capacity, increased fatigue, decreased productivity of arbitrary attention, increased task completion time with a simultaneous decrease in accuracy (Grigoriev & Khorseva, 2014; Grigoriev & Khorseva, 2018; Grigoriev, 2019) and more than 30 publications in peer-reviewed journals.

It should be noted that all the obtained psychophysiological indicators were below the norm or were at the lower limit of the norm.

It is important to emphasize that the results obtained considered the data of individual surveys of children and adolescents regarding the mode of working with mobile phones and the nature of the devices used.

In this regard, it is of interest to analyse the dynamics of changes in the mode of use of mobile phones for the entire period of observation. The estimation of the duration of use of mobile phone, daily load (min/day), method of use (the child brings the device to his ear, holding to your ear, use the speaker, etc.). Given that in these cases (2006) not all children who were under observation, had mobile phones, we had a unique opportunity to trace the dynamics of changes of psychophysiological indices with the start areas of mobile phone (i.e., at the beginning of the study, there was a control group, 67 school children who did not use mobile phone), but also to assess the change in the mode of using mobile phones.

At the beginning of the research, all students had mobile phones with a fairly limited set of functions: they could make a call, send a message or “play” simple games. In a study conducted from 2006 to 2009, the period of beginning to use mobile phones almost coincided with the arrival of the child in the first grade, so the duration of use did not exceed, as a rule, 0.5 years or 7 months. The duration of daily conversations ranged on average between 2-10 minutes / day for first-graders and 4-16 minutes / day for students in grades 2-4. All students in this period of time when using mobile phone brought it to their ears. As for middle school students, the duration of use was 1-3 years, and the daily use time already reached 25-27 minutes/day. Despite the fact that during this period of time, parents’ meetings repeatedly talked about the potential threat of mobile phone radiation to the health of children and adolescents, this information was perceived by parents with great scepticism. However, this continued until dynamic observations began to reveal changes in psycho-physiological indicators. First of all, this concerned changes in the response time to sound and light stimuli, an increase in the number of violations of phonemic perception, a decrease in performance indicators and an increase in fatigue parameters.

With the development of mobile communication and the advent of “advanced” devices, with the expansion of their functionality, the mode of using mobile phone has also changed. First of all, this affected the beginning of using mobile phone. For example, a survey of first-graders in the period 2009-2013 revealed a tendency to increase the number of children who started using mobile phones from the age of six and even from the age of five. The daily mode of use also changed: 2-15 minutes/day for first-graders, and with increasing age, the daily mode was already 11-18 minutes/day (less often more than 20 minutes/day). With the advent of the headset, students began to use it more often, but only for listening to music or audiobooks, and not for talking. In addition, during this time period, it was found that parents use their children’s mobile phones as an aid in (help, explanation) of homework. And due to the fact that not all mobile phone had hands-free functions, the child was forced to hold the phone, pressing it with his shoulder to his ear. In registered cases, the duration of such use could reach up to 1.5 hours per day.

Over the past 6 years, monitoring has continued at the Khimki Lyceum (formerly Lyceum No. 17) against the background of preventive measures that provide for the formation of a culture of using mobile phones, which is extremely important during the active development of a child’s personality. This was also facilitated by the expansion of the functionality of the devices themselves: the ability to use voice messages, video calls, a complete set of headsets, etc., which allows you to conduct a conversation without bringing the device directly to your ear. In addition, from the first days of monitoring, the director, the administration, the teaching staff of the Lyceum and the parents of students were actively involved in preventive work. In particular, the general meeting adopted the “Regulation on the mode of use of mobile devices during the educational process”.

The Lyceum has developed and implemented a series of preventive measures aimed at creating a culture of using mobile phones among participants in the educational process, based on the regulatory block (in accordance with the new legislation, recommendations of higher authorities and local regulations of the institution) and establishing the regime and rules for using devices during the educational process. The full cycle of activities includes implementation at all levels: administrative (legal and methodological support, strategy development), pedagogical (activities in classes and parallels, multi-age activities and research activities, diagnostics and correction), student (equal participation in the implementation of tasks, initiative, educational and research work), including with the involvement of official representatives of students. For the implementation of individual events, the participation of invited specialists is possible.

Over the entire period of observation, there has been an increase in the number of students (primarily in the primary level-grades 1-2) who do not use mobile phones: from 3.6 to 14.9% for different years of birth, which may be associated with those professional activities that are held in the Lyceum. According to the results of monitoring the use of mobile phones, it was found that the number of students (from 16.9% to 33.6%) who use the safe mode of using mobile phones (speakerphone, headset, SMS, messengers, video call, etc.) has increased from 13.4% to 19% of students are in the “transition to safe mode” (keeps near the ear at a distance of 2-5 cm, more often uses a speakerphone). The number of students who hold the phone to their ear during conversations decreased from 68.2% to 46.3% with a one-time reduction in daily use time. In particular, it was found that in the first year of the training, the number of students who spoke on a mobile phone for more than 30 minutes/day was in the range of 18-38% and gradually decreased year to year and remained in the range of 10%. Further analysis of the daily use of mobile phones showed the following rules being adopted. Among the first-grade students, the number of students with a daily load of more than 30 minutes / day ranged from 10 to 35%. Subsequent observations allowed us to establish a decrease in this indicator to 9.5-11%. In addition, during the transition from primary to secondary level, in different years observations showed an increase in the number of students with a daily use duration of more than 30 minutes/day to 18.3-24.9%. This can be due to both the psychological characteristics of adolescence, and, often, with the change of the device to a more “advanced” wireless devices. In general, excluding active users of mobile phones (more than 30 minutes/day), the daily use time decreased to 8.3-12.5 minutes/day.

Changing children's behaviors

By presenting to parents, their children and teaching staff information on the possible dangers to health of mobile phones there was a change in usage patterns. Using devices without the recommended restrictions allowed us to get tangible results. Analysis of the monitoring of psychophysiological indicators revealed that in students who switched to the safe mode of using mobile phones showed that psychophysiological indicators in almost all cases returned to the age norms (Marakhova & Khorseva, 2015; Marakhova & Khorseva, 2015; Marakhova, Brimova., Khorseva & Andrianova, 2016; Marakhova & Khorseva, 2016; Marakhova & Khorseva, 2017).

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A publication by Khorseva, Grigoriev and Grigoriev *Assessment of the EMF hazard of mobile phones for children and adolescents. Results of the only 14-year psychophysiological research in the world* (2019) was awarded a Diploma of the First Degree.at the XIX International Competition of scientific research works PTSCIENCE, 2020.

Recently, Russian government agencies have also paid attention to the problem of the negative impact of mobile phone radiation on the body of the younger generation. On August 14, 2019, the government published *Methodological recommendations on the use of mobile communication devices in general education organizations*. This was approved by the heads of the Federal Service for Supervision of Consumer Rights Protection and Human Welfare (No. MR 2.4.015019) and the Federal Service for

Supervision of Education and Science (No. 01-230/13-01). On January 10, 2020, the website of published recommendations to parents on the safe use of a mobile phone.

Our younger generation for the first time during the whole period of civilization, should be considered as at risk group, given the increased background RF-EMF in the external environment (Grigoriev, 2004, 2005, 2008, 2009; Grigoriev, 2019; Markov & Grigoriev, 2015) It is repeatedly mentioned in the decisions of Russian National Committee on Non-Ionizing Radiation Protection (RNCNIRP). from 2001, 2004, 2007, 2008 and 2009. The texts of these decisions are given in the book by Grigoriev and Khorseva (2014).

Unfortunately, currently there are no hygienic regulations for the impact of RF-EMF on the child's brain. This was raised in 2001 by the RNCNIRP. This committee in 2002 recommended that children, teenagers up to 18 years of age and pregnant women should not to use mobile phones. These recommendations were subsequently considered in the preparation of SanPiN 2.1.8/2.2.4.1190-03. In addition, the relevance of this problem has been repeatedly highlighted in the works of Russian scientists (Grigoriev, 2004; Grigoriev, 2004; Grigoriev, 2005; Grigoriev & Grigoriev, 2013; Grigoriev & Khorseva, 2014).

In many countries (USA, Canada, India, Israel, Germany, Great Britain, Belgium), various temporary recommendations on the mode of using mobile communication by children and adolescents in educational institutions have also been developed (American Academy of Paediatrics: Protect Children from Cell Phone & Wireless Radiation 2013.

In 2017, the International Conference "Children, Screen Time and Wireless Radiation" was held in Reykjavik and was attended by scientists from around the world.. They signed a petition about the dangers of using wireless technology in schools for children. This appeal was signed by scientists from Sweden, Great Britain, Australia, France, and Russia etc. from a total of 27 countries, including the author of this monograph from Russia (Grigoriev, 2017).

The scientific community is far away from solving the problem of assessing the risk of exposure to RF-EMF in children's brains. Both abroad and in Russia, there is no corresponding scientific radiobiological basis for establishing a safe threshold level of

RF-EMF with fractional long-term exposure to the child's brain.

We present the opinion of Markov M., who has repeatedly given a summary assessment of the current situation associated with the global previous impact of EMF on the population (2015, 2018, 2019):

> *The twenty-first century is marked by exponentially growing development of wireless communication technologies. The entire biosphere and every organism living on this planet is exposed to the continuous action of complex and unknown (in terms of sources, amplitudes, frequencies) electromagnetic fields*.

The danger of high-frequency electromagnetic fields used in the communication of the XXI century is often referred to as "contradictory", the theory of the so-called thermal action is absolutely wrong. This is not a controversial issue, it is a conflict of interests between industry on the one hand, and civil society and the environment on the other.

Particular attention should be paid to the potential damage that twenty-first century society causes to children. These are the realities of our life and now it is impossible to protect children from "cocktails" of electromagnetic radiation in the XXI century. Children are the most aggressive part of users of wireless devices, from toys to tablets and smartphones. And the worst thing is that their body and brain have been exposed to RF-EMF almost since they were born, in most cases they start using computer toys at the age of one year. The effects of RF-EMF on newborns and older children will be longer and stronger than the effects on their parents.

Radiation protection standards for 2G, 3G and 4G technologies

Our radiation protection standards are intended to protect human health by guaranteeing the safety of non-ionizing wireless radiation exposures to the public. The fifth generation of wireless technologies (5G) has introduced new sources of electromagnetic field exposures that will be used in tandem with the existing 2G, 3G and 4G technologies. Despite these newly added exposures, the wireless industry has largely retained previously existing exposure limit recommendations that are based on acute heating. To further our understanding of the details of this problem today, it is important to thoroughly examine the rationale for this decision which has national regulatory implications.

The main stumbling block to a material revision of the previously recommended standards is the ICNIRP itself. This international organization, based in Germany, is a non-governmental organization (NGO) whose funding sources remain opaque. There are currently public appeals by scientists asking Germany to withdraw their portion of funding support (Hardell & Carlberg, 2020). It is the ICNIRP's recommendations that dominate the setting of safety guidelines around the world. For more than 20 years, the ICNIRP members have had blinkered views when determining NIR EMF standards. They have focused narrowly on acute, very short-term and thermal effects of radiofrequency radiation, which contradicts real-life radiation bioeffects and exposure situations. This state of affairs is recognized by many domestic and foreign scientists (Grigoriev, 2017; Hardell, 2017). Nonetheless, the ICNIRP opinion, supported by the WHO and major telecommunications companies, continues to be used by most countries of the world.

Some countries have independently introduced stricter standards, even more so than the Russian standards (10 μW/cm^2) which have been comparatively more stringent for over 30 years. To date, more than twelve countries have introduced regulations that are tighter than we have in Russia. Examples are Austria, Italy, Canada, Belgium, China, Spain, Brazil, Bulgaria and Poland (see Figure 20). The reasoning behind the decision in these countries is based on the recognition by EMF scientists that low-level exposures can trigger non-thermal bioeffects in organisms, and that biological effects from low-level RF-EMFs may have long-term health consequences. Thus, these countries have taken a *precautionary approach* when setting limits. There is currently a wide differential range of power densities measured in various countries—from 0.006 to 1000 μW/cm^2 (Grigoriev, 2018). The "BioInitiative" group is an independent scientific working group consisting of 29 scientists from ten countries. Based on an analysis of many of their own studies together with a number of collated published results (about 2,000 publications), they recommended setting maximum power density levels at 0.0006 μW/cm^2. This is currently incompatible with the modern world's NIR exposure levels. Since the end of World War II, RF-EMF power densities have increased by a quintillion.

ICNIRP suggests measuring only *average* values of radiofrequency radiation. However, interference and effects between pulses from different RF sources can result in short-term pulses with higher power densities than the recommended ICNIRP average power density limit of 10 W/cm^2 (Puranen, 2018).

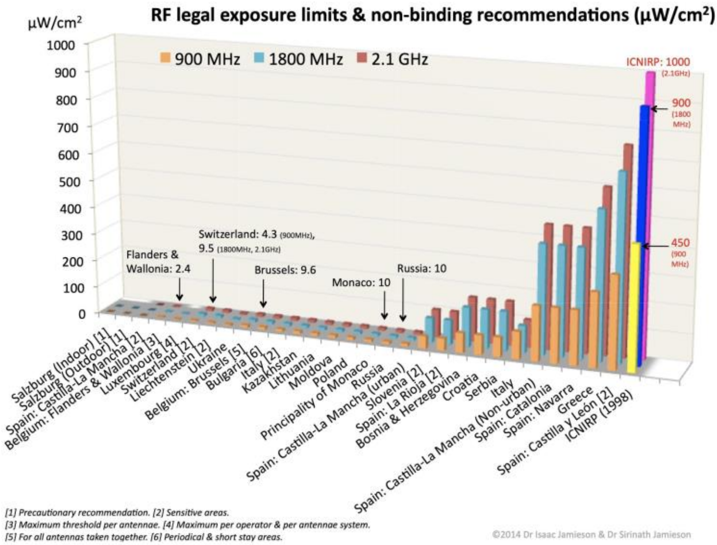

Figure 20: Tightening of various European regional and state standards for chronic exposure to RF EMFs over the past 23 years (Jamieson, 2014)

It has been clearly demonstrated that the use of mean values for radiation exposure can lead to an underestimation of the risk of exposure (Chavdoula et al., 2010). Intensity, frequency, duration of exposure, specific conditions of the use of devices, polarization, pulsation and modulation are all key parameters for assessing the biological activity of

EMFs (Grigoriev, 1996). However, the actual effect of the burst of power density can be far stronger than one would expect when seeing only "averaged" values (Zhavoronkov & Petin, 2018).

A crucial issue in standard setting is the ongoing controversy over the *mechanism* of biological action of RF-EMFs—whether this is *thermal* or *non-thermal*. This question has been an enduring topic of discussion for 30 years. Standard setting authorities (such as ARPANSA in Australia) require both *evidence* of adverse biological effects, as well as an understanding of the *mechanism* of these effects before incorporating protective provisions in their standards. Non-thermal mechanisms clearly exist (as described by Geesink and Meijer (2020)), and they can have both therapeutic and detrimental bioeffects on biology.

A recent European Parliament presentation by Belpoggi evaluated evidence of carcinogenic and reproductive/developmental effects from 2G-5G RF technologies. The results indicated that 2G-4G frequencies (450 to 6000 Mz) are "*probably* carcinogenic to humans" and "affect *probably* man and *possibly* woman fertility"; they also "may *possibly* have adverse effects on the development of embryos, foetuses and newborns" (Belpoggi presentation, "Current state of knowledge of 5G-related carcinogenic and reproductive/developmental hazards as they emerge from epidemiological studies and in vivo experimental studies", 2021).

The current wireless frequencies and modulations that have been selected for communication uses are biologically active and unhealthy.

While various commissions have been established, and numerous international meetings, round tables, and informal forums have been held, they have all, unfortunately, retained sole recognition of the *thermal* mechanism of biological action of RF-EMFs alone. This has been due to the predominating influence of the telecommunications industry which has actively supported the view. For example, the industry has funded only those RF-EMF bioeffect exposure studies where a negative result was predictable—that is, where a "no effect" result would be found. There was also manipulation of methods used in conducting experiments, and selective methods of statistical processing occurred. Some scientists were biased. In this way, the weight of scientific evidence has been skewed by industry influence on this question. It is clear that an effective manipulation of science has been used to exclude the recognition of non-thermal effects.

By dogmatically upholding a deficient thermal-only view of RF-EMF effects over many years, the WHO Advisory Committee, ICNIRP, IEEE and ANSI have revealed themselves as scientifically bankrupt. In 2011 these multi-organizational shortcomings, and their implications for public health protection, were acknowledged by the Parliamentary Assembly of the Council of Europe, who adopted Resolution 1815. This resolution recognizes the potential threat to public health and the environment from electromagnetic field exposures. Many peer-reviewed foreign journals have published criticisms of the work of the organizations mentioned above, and pleas for the revision of exposure standards.

Numerous demands for a revision of the international recommendations compelled ICNIRP to start this process. A version of the updated guidelines was planned for completion in mid-2018. Bizarrely, it was revealed that, due to insufficient funding, the review would be delayed until March 2020. When the newly updated RF guidelines were released, ICNIRP claimed that they were *more appropriate ... for the higher frequencies that will be used for 5G in the future*. Chairman, Eric van Rongen, said that ICNIRP hoped they would *help put people at ease* (ICNIRP media release, 2020). It should be noted that at the time, of writing this book, the population continued to be exposed to RF-EMF around the clock, under the old ICNIRP 2002 (2-300 GHz) standard of 1000 $\mu W/cm^2$ (10 W/m^2) for 6-minute averages. In the new ICNIRP 2020 guidelines, the frequency grouping changes ($\geq$ 6 - 300 GHz) for 6-minute averages and the basic restriction has been relaxed by a factor of 2, thus increasing it to 2000 $\mu W/cm^2$ (20W/m^2). The old limit of 1000 $\mu W/cm^2$ (10W/m^2) has now become the new whole body 30-minute average exposure. With the longer period over which measurements are taken, this essentially reduces the limit by a factor of 5.

In 2017, the WHO organized a joint meeting in Munich between the two international organizations responsible for developing worldwide radiation protection systems: the International Commission on Radiological Protection (ICRP) and the International Commission on Non-Ionizing Radiation Protection (ICNIRP). The main topic was to find mutual understanding of approaches to international radiation protection systems.

There was an exchange of information and opinions on the ethical and scientific foundations and principles of protection of the population. However, the hope was not justified as ICNIRP did not consider the rich experience of the ICRP in regulating ionizing radiation and retained their platform of the "thermal" action of EMF.

In Germany in 2020, Whistleblowing International, a group of legal professionals and investigators, initiated the Mobile Phone Whistleblower Project to uncover hidden information about the health risks of mobile phones. The group encourages citizens, especially current and former employees of Motorola and other mobile phone companies, to report information "about fraud, deception, corruption or other misconduct in the mobile industry". They found that Motorola, oddly enough, operated a radiofrequency research laboratory at their Plantation headquarters in Florida from 1993 to 2009:

> *After opening the laboratory, Motorola began to shape the direction of mobile phone research and public discourse. The company played a significant role in funding research, deciding which scientific studies should be conducted, serving on editorial boards of scientific journals, and overseeing standard-setting organizations that determine official radiation exposure limits.* ("Group Calls on Citizens to Blow the Whistle on Motorola Cell Phone Safety Studies", Corporate Crime Reporter website, 2020)

The most influential organization was the Institute of Electrical and Electronics Engineers (IEEE).

The situation described above has been extensively covered in the monograph *Cellular Telephone Russian Roulette* by Robert C. Kane. Kane, a research scientist and product design engineer, was a cell phone communications industry insider from its early years. He lays bare the industry's foreknowledge and machinations of the scientific evidence on cell phone health hazards, as well as their propagation of disinformation to the public: "Never in human history has there been such a practice as we now encounter with the marketing and distributing of products hostile to the human biological system by an industry with foreknowledge of those effects" (Kane, 2001).

Since then, to our great regret, nothing appears to have changed. Despite numerous publications, both in Russia and overseas, and the direct participation of one of the authors of this book in discussions to address these issues, it is clear that the strategy of disinformation to the public continues into the 21st century. In the United States, Oxford University Press published two monographs by the epidemiologist and public health practitioner, David Michaels, that address the pernicious problem of industries undermining scientific consensus and manufacturing perpetual uncertainty: *Doubt Is Their Product: How Industry's Assault on Science Threatens Your Health* (2008), and *The Triumph of Doubt: Dark Money and the Science of Deception* (2020). These books expose the misinformation and deception that have become endemic to industry-influenced science, and that distort important scientific data to the detriment of public health (see Figure 21).

Figure 21: The books of Dr David Michaels, author, epidemiologist and public health advisor: Doubt Is Their Product: How Industry's Assault on Science Threatens Your Health and The Triumph of Doubt: Dark Money and the Science of Deception (Oxford University Press, 2008 & 2020)

Michaels, the author of the monographs, was the longest-serving chief safety administrator in America's Occupational Safety and Health Administration (OSHA) for seven years.

Reviews of *The Triumph of Doubt: Dark Money and the Science of Deception*:

David Michaels's new book, The Triumph of Doubt, ... examines how frequently, and easily, science has been manipulated to discredit expertise and accountability Sheril Kirshenbaum, review in *science,*

"Few people have done more to document disinformation about science than David Michaels. His new book is an important addition to the growing literature on doubt, disinformation, and deception. Naomi Oreskes, author of *Merchants of Doubt"*

The Triumph of Doubt is a brave and important book, raising the alarm about the systemic corruption of science. Feilicity Lawrence, review in *Nature* (Website: https://www.drdavidmichaels.com/books)

It is unsurprising then, that the ICNIRP radiofrequency guidelines have continued to provide inadequate protection for human health for decades (Grigoriev, 2017). Clearly, the rigid assertion that a thermal mechanism is the only plausible or valid mechanism of biological action of RF-EMFs, is a deliberate distortion of the facts.

The result of all of this, is that there is a variety of recommended exposure limits for RF-EMFs, varying from 0.0006 $\mu W/cm^2$ to 1000 $\mu W/cm^2$. Meanwhile, under these standards, the public are exposed to a vast assortment of harmful NIR which continues around-the-clock. This situation flies in the face of radiation health protection principles for both ionizing and non-ionizing radiation, which advise that standards should be harmonized in order to minimize harmful exposure.

This situation can be characterized as an unethical and uncontrolled experiment on the public. Endorsed by a partisan group of scientists, and without the restraint that harmonized standards would provide, there is no care for the consequences. We have already mentioned that ICNIRP is a "Private Club" in which new members are chosen by the ICNIRP members themselves—thus only scientists who hold the same viewpoints are admitted and allowed to participate. As a consequence, in ICNIRP, bona fide scientific discussion does not occur, and consensus is not the produce of true scientific debate. Thus, a serious moral crisis has been created—where far-reaching public health protection recommendations (health and safety standards of RF-EMFs) are actually determined by the telecommunications industry itself as it strives to optimize financial profits, and in defiance of the views of the scientific community.

The ICNIRP exposure limit mentioned above applies to whole-body (or far-field) radiation exposures, such as those from base stations and Wi-Fi. It is critical to note, however, that *within* the limits of this recommended dose, serious pathological processes can develop when the RF exposures are *chronic*. This is confirmed by the results of a series of Russian-French experiments conducted in 2009 at the SRC-FMBC (the Russian State Research Center − Burnasyan Federal Medical Biophysical Center of the Federal Medical Biological Agency) showing effects on autoimmune processes (Grigoriev, Grigoriev, Ivanov et al., 2010; Grigoriev, Grigoriev, Mikhailov, Ivanov et al. 2010; Grigoriev, Grigoriev, Ivanov et al., 2010; Yu. G. Grigoriev, 2011).

The fruitless debates on thermal versus non-thermal mechanisms of RFR-EMF biological action continue to drag on. At the same time, in the absence of universally agreed (or "harmonized") standards, the population is being subjected to ongoing, uncontrolled RF-EMF exposures—even though we have already detected the presence of abnormal pathology in cell phone users within the *current* ICNIRP standards.

Conclusion: Integrated risk assessment of 3G, 4G and 5G

Rational regulation of the future telecommunications initiative requires careful assessment of risks to human health and the environment. Today, a 5G standard is being aggressively implemented for global cellular communications, working with millimeter waves. It is important to give a summary assessment of the danger to the population not only of 5G, but also of previously used standards together.

A completely new problem arose in connection with the use of cellular communication of the 5th generation: What should be the current approaches to assessing public health risks?

The 5G standard uses millimeter wave EMF, which a significantly different frequency than 2G, 3G, and 4G technologies. However, the lower frequencies will still be used. This will lead, on the one hand, to an additional impact of EMF on the population, but, on the other hand, the possible bioeffects will be completely different. Critical organs are the skin and eyes (sclera). In this regard, it is a mistake, from our point of view, when only a simple arithmetic addition of the absorbed dose of the 5G standard to the already existing 2G, 3G and 4G standards is used in the hazard assessment and rationing. In our opinion, this is a wrong and counterproductive approach. This may explain the failure of the scientific community to recognize the existing FCC radiation protection standards, developed back in 1996.

The hazard assessment must be far more adequate, considering the total electromagnetic load on already existing critical organs and systems, their possible adverse interaction in the formation of a healthy status of the body.

From our point of view, it is most productive to conduct a hazard assessment considering the total electromagnetic load on already existing critical organs and systems. It is necessary to consider the significance of the influence of possible impaired functions of irradiated critical organs and systems on the formation of a healthy status of the body during lifetime exposure to EMF of the population.

In our opinion, the brain, the sensory systems of visual, auditory and vestibular analyzers, the thyroid gland, the skin of the body, the sclera of the eyes, the reproductive and immune systems can be considered critical organs when exposed to cellular EMF, including a 5G standard. Of particular importance for the assessment of dangerous long-term consequences, such as malignant tumors, is to be include in EMF exposure under chronic exposure. Of course, the greater vulnerability of children to the effects of cellular EMF should be considered.

This approach to the assessment of the total radiobiological danger of planetary electromagnetic radiation exposure of the population is more adequate, it considers the possible adverse effect of complex EMF exposure of all three standards being 3G, 4G and 5G on the most radiosensitive functions of the body, which, of course, will increase the risk of danger to public health.

We can predict a change in our traditional way of life.

It is important to start large-scale state scientific research in Russia to assess the impact of cellular EMF on the health of all population groups. Children are one of these groups that need special attention.

It is necessary to assess the degree of radiosensitivity of various organs and their interaction with the biological system of the body. These vital organs develop over the course of our lives and should be considered when setting safety standards. This is necessary to assess potential adverse reactions to important organs such as the brain, visual and auditory effects, and vestibular analyzers, the thyroid gland, the sclera of the eyes, the reproductive system and the immune system. The study of the effects of long-term or chronic radiation exposure, such as benign and malignant tumors, is particularly important for assessing the risk of all forms of EMF. We urgently need specialized research to assess the degree of danger of cellular communication for children. It is important to establish a scientific basis for developing optimal hygiene standards with a built-in “safety factor” to address unknown factors related to health impacts, as well as possible future technological developments.

Recommendations for public health: what needs to be done today

We recognize that cellular communication is now an integral part of our everyday life, in the development of social communications, in solving digital technology economic problems. There is no return to using a conventional cable communication system. However, wired connections are still preferable and a viable option in many cases (Schoechle, 2018).

Currently, we do not see the possibility of reducing the electromagnetic load for the population when exposed to MMW (5G standard). In fact, the 5G standard is still in development. There are also no relevant publications and proposals in other countries. Classical radiobiology uses two methods of protection against all types of radiation protection by distance and time. In this situation they are not applicable. The very idea of 5G technology provides for the provision of permanent forced contact of the MMW of populations around the world regardless of its location and the desire to avoid this contact.

Of course, radical technical solutions are needed to reduce the electromagnetic load on the populations. It is important to expand scientific research on state programs. Global lobbying by industry representing their financial interests for the Internet must be stopped.

It is necessary to harmonize radiofrequency standards so that they are consistent with the available results of numerous scientific studies and are free from biased experts and executive committees at international levels.

To obtain a tangible effect in reducing the electromagnetic load on the population, in our opinion, it is necessary to involve the population in this serious process. It is important to change the existing attitude of the population to cellular communication, it should not be just on consuming of the technology from a consumer's perspective. There should be objective information about the existing health risks, as was done with regard to ionizing radiation after the Chernobyl nuclear accident. All age groups of the population should clearly know that EMF of cellular communication belong to harmful types of radiation and unreasonable and unjustified use of this communication (long conversations on household topics, pointless “chatter”, complete rejection of cordless home phones, etc.) can negatively affect health.

The information received that EMFs are harmful types of radiation and require strict compliance with radiation protection–recommendations should be actively and constantly communicated to all groups of the population and, above all, through the media. Currently, in the media in Russia and abroad, there is a flow of information that EMF exposure to cellular communications is safe. As a rule, these conclusions are made by experts of who are ignorant of the bioeffects of wireless communications and their specialties lie in others area of radiation protection and medical application. A number of scientists and clinicians who are advocating for full safety are ignorant of long-term consequences of these bioeffects for the health of the populations. Others advocating for full safety have a conflict of interest and are part of the industry funded research.

The public should be made AWARE that EMFs can have a negative impact on health if the recommended standards are not met. The population of all ages should strive to reduce the electromagnetic load on their body. For example, choosing a particular device for yourself and your child, set the time mode of using a mobile phone, increase the distance between the brain and the EMF source, i.e., independently choose and follow the optimal ways to reduce the level of electromagnetic exposure.

We must radically change the attitude of the population to cellular communication!

We have proposed that the category of “voluntary risk” be introduced for the population, i.e., independent choice of the type of use of cellular communication, to use or not two classical methods of protection being “time” and “distance”, i.e., it is necessary to reduce the conversation time and increase, if possible, the distance between the EMF source (mobile phone) and the brain (Grigoriev, 2003, 2017, 2020). However, from our point of view it would be optimal to name this preventive strategy as “Conscious Risk”. The adoption of Conscious Risk will dramatically reduce the daily electromagnetic load on the population. Currently, the entire population, including children, should take active, conscious preventive and protective measures to reduce the electromagnetic load on the body.

Professor Yuri G. Grigoriev, November 2020

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