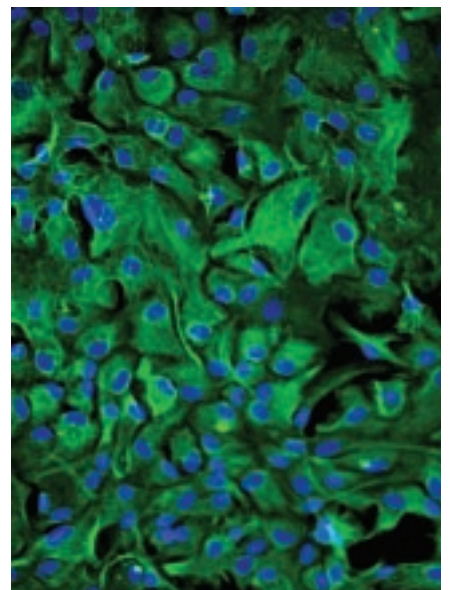
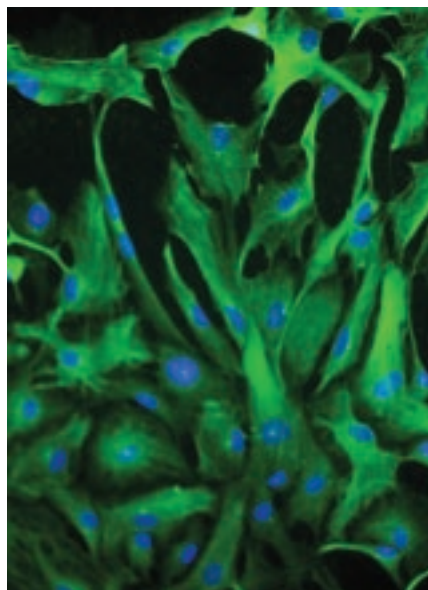
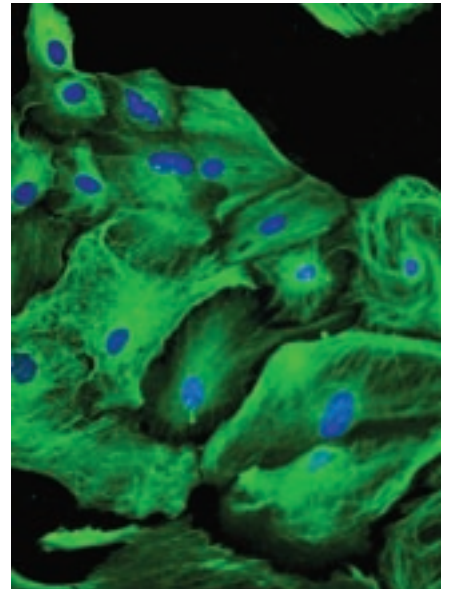
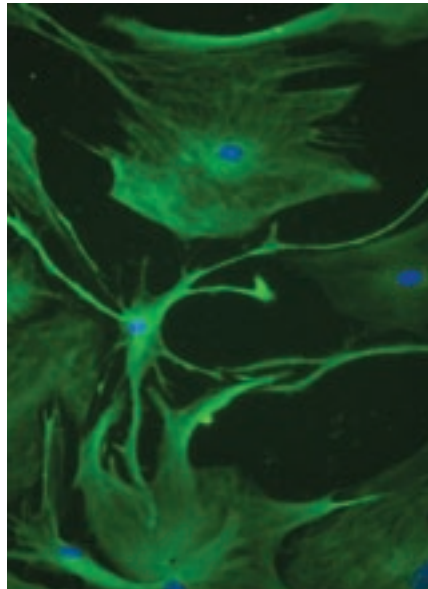


June 23 to 27, 2002, Québec City, Canada

# 24th Annual Meeting of the Bioelectromagn

by Helmut Franke

With this report, the Research Association for Radio Applications introduces a new rapporteur and author, Dr. Helmut Franke doing biochemical research especially in the field of the blood-brain barrier. At the BEMS 2002 he held a lecture on this topic.



*immunofluorescences in astrocytes of rat  
green: GFAP – glial fibrillary acid protein; blue: nucleus anti-staining using DAPI*

# etics Society (BEMS)



## Preface

This year's contributions to the annual meeting dealt with issues from following areas: transcranial magnetic stimulation (non-invasive magnetic stimulation passing through the skull), in vitro studies, in vivo studies in animals, in vivo studies in humans, pain etiology and treatment, radiofrequency dosimetry, emerging therapies, medical applications, epidemiology, mechanisms of interaction, radiofrequency fields and cognition, presentation of the REFLEX program. In the following, we will give an overview of selected contributions from my perspective focusing on the area of risk assessment for mobile radio telephony.

## Transcranial magnetic stimulation

The first plenary session dealt with the potential of transcranial stimulation (TMS), that is, localized magnetic stimulation of specific brain areas with very high magnetic field strengths of 1 T and above using a coil.

Ueno (Tokyo, Japan) described tests performed using a figure-of-eight shaped coil instead of the usually applied circular TMS coil. By stimulation of different brain regions or vectors (1 T; 0.1 to 0.2 ms), single finger or facial movements can be induced. Ueno reported a TMS-induced disruption of associative learning. During a memory

test subjects had more difficulties to memorize symbolic pairs if a right frontal brain region was exposed to TMS. Further, Ueno introduced a possible therapeutical approach for the treatment of central nervous system diseases such as depression and Parkinson's disease. In laboratory, he was able to show that Parkinson-like symptoms such as damaged hippocampal cells in rats were repaired when repetitive TMS (pulses of 1.2 T over 48 h) was applied.

Rothwell (London, United Kingdom) also spoke about cognitive response disturbances in test subjects. In an interesting experiment he could show that TMS stimulation of the visual cortex interfered with blind people reading Braille, whereas normal people failed to detect disturbances when scanning raised letters. Thus he concluded that the optical center of blind people is activated when reading Braille. Rothwell added that all effects produced by TMS are only temporary.

## Lecture series: In vitro studies (sessions 1 and 3)

During the session dealing with in vitro experiments, Nindl (Terre Haute, USA) illustrated therapeutical effects of electromagnetic fields (EMF) on inflammatory diseases. Human Jurkat cells were examined as a model for T-lymphocytes of the immune system in three different states – the normal proliferating state, the apop-

otic state, and inflammatory T-lymphocytes. Each group was exposed to pulsed magnetic fields with amplitudes of 5 to 20 mT. Whereas normal Jurkat cells showed no effects and apoptotic cells showed only minimal effects, in inflammatory cells Nindl observed a doubling of the interleukin-2 level and a decrease in proliferation rate of up to 30%. EMF effects that are dependent on the cell cycle potentially open up possibilities to modulate inflammation processes without leading to negative effects on the immune system.

### **The study on the blood-brain barrier of Leszczynski**

Special attention was given to a contribution of Leszczynski (Helsinki, Finland). According to the title of his lecture, the author identified a mechanism at the molecular level explaining damaging effects on the blood-brain barrier (BBB) from mobile phone radiation. His recent publication in the journal *Differentiation* (*Differentiation* 2002, 70:120-129) which now an issue of intense debate in the media, as well claimed that the work of this Finnish group will provide new basic insights into this issue.

However, Leszczynski did present only hypotheses and postulations on the effect of the observed interaction on the blood-brain barrier. Interestingly, the EA.hy926 cells he applied do not represent the BBB but instead are cell cultures taken from the umbilical cord. Neither morphology, that is, the appearance of cells, as shown in the presented photos, confirmed similarities to the typical spindle shape of BBB endothelial cells. Their most important property, the barrier function of the so-called tight junctions, was not dealt with, either.

At exposure to mobile radio waves (GSM 900; 2 W/kg; 1 h), under non-thermal conditions, Leszczynski found an increase in phosphorylation of the heat shock protein 27 (hsp27), as well as an increased expression of the proteins hsp27 and p38-mapkinase. However, the photos documenting indirect immunofluorescence staining also shown during the lecture were not convincing. The same goes for the induction of stress fibers - actin filaments - in cell cultures he demonstrated.

Further he reported a screening obtaining more than 1,200 different signals by two-dimensional gel electrophoresis and western blots, among them more than 300 of phosphoproteins showing an altered degree of phosphorylation after mobile phone radiation. Out of these, to date he has been able to identify only one, the above mentioned hsp27. An association of this finding with a damaging of the barrier function of the BBB as yet is only hypothesized, as he repeatedly emphasized. Neither in the lecture nor in the subsequent discussion, he commented on the aptitude of the EA.hy926 cell culture as a BBB model. Therefore, the paper does not really provide new facts related to electromagnetic field effects on the blood-brain barrier.

### **Studies on heat shock proteins, lymphocytes, neurites, density of meninges and the BBB**

Sontag (Karlsruhe, Germany) examined the inductivity of the heat shock protein hsp72 by low-frequency EMF (0 to 60 Hz; 1 mT; 15 min) in human HL-60 cells. Two hours after exposure he observed a maximum increase of the hsp72 level. The found effect was frequency-dependent: A statistically significant increase was observed

only at 20 Hz and 50 Hz. During the discussion following this contribution, it was pointed out that another heat shock protein - hsp70 - can be induced already at 100fold smaller magnetic field strengths in cell cultures.

Belyaev (Stockholm, Sweden) examined the effect of ELF and microwaves on lymphocytes from electrosensitive and healthy humans. However, the sample of only seven tests each did not provide clear evidence that might explain the phenomenon of electrosensitivity.

Herbst (Edgewater, USA) observed no effect of EMF (0.3 mT; 2 Hz) on neurite growth in a chick embryo model.

Veyret (Bordeaux, France) reported on experiments investigating the dura mater and blood-brain barrier density. Rats constrained in a tube were exposed to mobile phone radiation of the GSM 900 standard (2 h; 0.12 to 2 W/kg average over the whole brain). Two types of rat were compared: normal rats and such with artificially induced chronic meningitis. The extravasation of a marker was observed: of the fluorescence-marked bovine serum albumin (BSA). In this system, apart from a calculated value, also a SAR value measured „at the site“ can be determined via the temperature rise measured by a thermistor probe. Remarkably, the measured SAR value always amounts to nearly half of the calculated SAR value.

At measured 0.2 W/kg, no signal different from control was observed in the blood vessels; at 0.9 W/kg, Veyret found a weak, and at 3.5 W/kg a strong signal indicating a considerable extravasation of the marker protein FITC-BSA. In brain slices, after exposure to a SAR of 2.7 W/kg (calculated 5.3 W/kg) measured at a depth of 5 mm, a strong extravasation of BSA could be detected, whereas at 1.3 W/kg and 0.3 W/kg



no BSA leakage across the blood-brain barrier could be observed.

Thus, results show both an increase in permeability for the dura mater which has no explicit barrier function, as well as for the BBB. However, presented qualitative values were not comparable since the fluorescence signal for the BBB was strongly amplified by an antibody reaction to the marker protein. For the test on dura mater permeability, photos show only the intrinsic fluorescence of the marker protein.

SAR values for which Veyret observed a strong migration of markers through blood vessels, are quite high with 3.5 W/kg and 2.7 W/kg, respectively, exceeding the recommended local limit value for the head (2 W/kg).

The blood-brain barrier was also the focus of the group around Masuda (Tokyo, Japan) using EMF exposed rats (1 h/day, 5 days/week, 4 W/kg average in the brain; 1.439 MHz). Through a cranial window no alterations in leukocyte behaviour and no interference with the BBB function were observed. Quantification of BBB density performed by applying fluorescence dye, was not convincingly illustrated by the presented photos. The question why especially blood vessels of the soft meninges without barrier function were applied as a model for BBB examination was not answered.

With his experiments, Gottwald (Karlruhe, Germany) made clear that an increased mRNA concentration at the cellular level has not necessarily an effect on protein expression. Though, after exposure of a liver cell culture (HepG2) to low-frequency magnetic fields (50 Hz; 1 mT; 15 min), he was able to measure a strong increase in concentration of mRNA responsible for coding the heat shock protein 72,

there was no correlating increase in protein expression.

A result contradicting the often claimed risk of cancer initiation by EMF was presented by Perrin (La Tronche, France). Bacteria exposed to pulsed fields (2.45 GHz; 217 Hz modulation; 3.3 W/kg) demonstrated a significantly decreased mutation rate compared to the control group if treated with a cancer-inducing substance. McNamee (Ottawa, Canada) neither could detect genotoxic effects on human leukocytes if they were exposed to an amplitude-modulated field of 1.9 GHz (as emitted from digital PCS mobile phones) with up to 10 W/kg over a period of 2 to 34 h. A similar result was found by Sasser (Washington, USA); in his study supported by Motorola, he neither could observe cancer initiation in rats having been exposed for 2 h/day, 5 days/week over 2 years (SAR 0.16 W/kg and 1.6 W/kg).

#### **Lecture series: High-frequency and brain function (session 4)**

An overview of the controversial debate on effects of mobile phone radiation on the human brain was given by Morrissey (Fort Lauderdale, USA). He showed that there equal numbers of studies demonstrating negative effects and of studies not detecting any effect. Often, shown effects, though statistically significant, are of very low intensity, or cannot be reproduced by independent laboratories. On the whole, the studies he examined do not provide evidence for an effect based upon a known mechanism. Thus, especially at this mechanistic level, further research is required in order to gain a better understanding of the interaction between EMF and biological systems.

#### **Lecture series: In vivo studies – animals and humans (sessions 5 and 6)**

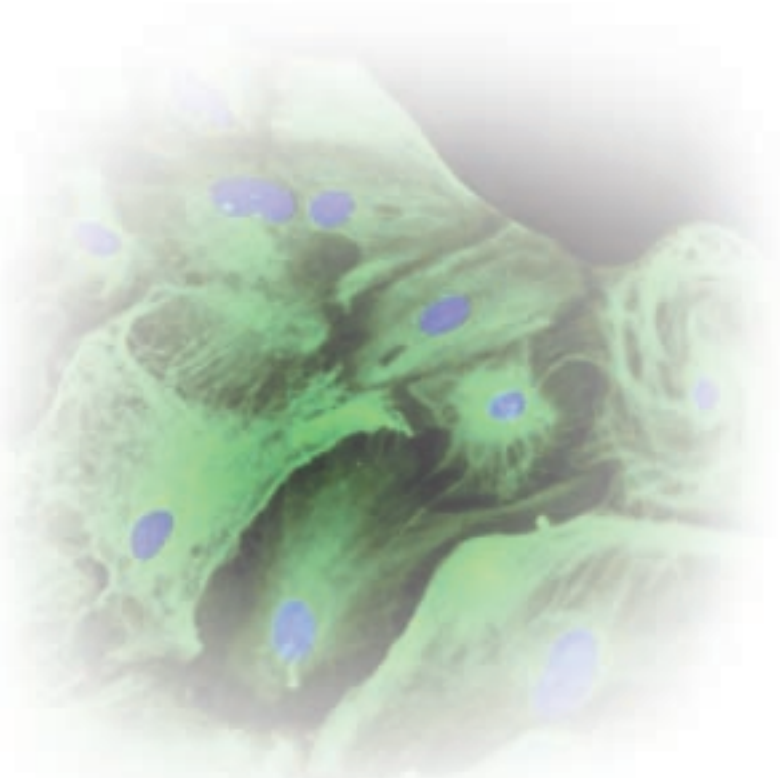
In her lecture, Fedrowitz (Hannover, Germany) emphasized that substrains of typical laboratory rats (Sprague-Dawley rats) have developed showing different responses when using identical test designs. Therefore, the selection of the animal strain to be used in experiments aiming at replicating results of other research groups is crucial. Whenever possible, researchers should seek to use the same source of test animal supply.

During his tests on heating phenomena on the skin surface and in epidermis caused by mm-wave radiation (75 GHz), Alekseev (Philadelphia, USA) observed a subcutaneous maximum heating. Further he could show that a heat conduction to deeper dermis layers occurs. Therefore, a possible damaging of tissue by overheating should be considered for the deep dermis beyond maximum penetration depth of mm-waves (caused by wavelength), too.

Firmly, Adey and Elder (Motorola Florida Research Labs, Fort Lauderdale, USA) denied an association between EMF and health hazards. In a review, Elder demonstrated in data taken from selected studies that there is no basis for assuming an increased risk for children from mobile radio phones. The subsequent discussion was heated. Many attendees disagreed with his argumentation that was thought to be quite sloppy; Elder himself had not much to say about the objections raised by the audience.

#### **Plenary session: Pain treatment**

In his contribution to the plenary session on pain, Thomas (London, Canada) pointed to potential applications of pulsed



electromagnetic fields for the treatment of chronic pain patients. However, he did not exclude that at least part of the promising results could be explained by the placebo response.

### Lecture series: Dosimetry (session 7 and 9)

Bitz (Wuppertal, Germany) spoke about the exposure of subjects to the near-field of multi-band base station antennas. The determination of safety distances for occupational exposure (for example technicians, roofers, chimney-sweeps) in front of mobile radio base station antennas is based upon recommended limit values of the exposure level 1 for the specific absorption rate (SAR). Since the specific absorption rate is difficult to determine in operational practice (there are no portable devices for SAR measurement), the Chair of Theoretical Electrical Engineering has developed a complex method for numerical calculation of electromagnetic near-fields of mobile radio antennas in order to determine required SAR distributions using computerized models of the human body.

In this context, he presented a new human model for measurements. In accordance with the CENELEC recommendations,

this model now has a weight of only 42 kg instead of the 110 kg commonly used. The lecture particularly dealt with the problems of exposure in front of multi-band base station antennas, that is, antennas simultaneously operated in different frequency bands (for example GSM and UMTS networks). In this case, the exposure is determined by the superposition of all SAR distributions for the single frequency bands.

In his lecture, Schmid (Vienna, Austria) described the decrease in electric conductivity of the brain after death (over more than 20 h). Since measurement systems for the calculation of (frequency-dependent) conductivity are based on data gained in dead brains, Schmid points out that conductivity in the living brain can be up to 20% per cent higher.

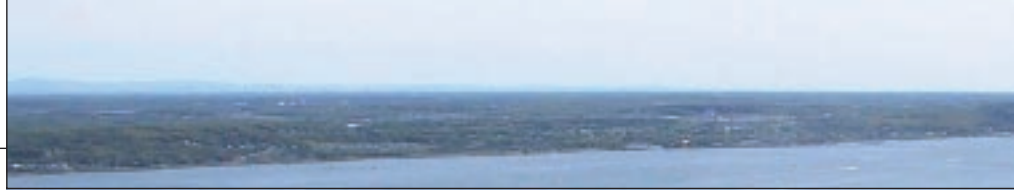
### Child head models for numerical calculations

In past calculations (1996), Gandhi (Salt Lake City, USA) had determined higher SAR values and penetration depths in a child head model. These results often cited in the media are one of the reasons for recommending that children should as far as possible abstain from using mobile phones. Based upon this, the group around Guy

(Seattle, USA) developed allegedly more accurate child head models by metrically reducing the size of the adult head model. Both models are distinguished only by the method used for reducing the adult head model. Whereas Gandhi reduced the size of voxels (that is, spatial units for computerized calculation), Guy applied a smaller number of voxels. In his head models of a 5- and a 10-year old child, Guy could not detect any considerable difference from the adult head. The maximum SAR in a smallest volume unit (voxel), in a gram of brain tissue as well as penetration depth were compared.

The animated discussion following this lecture focused on the uncertainties inherent to such models. None of the models was preferred by a majority of discussants. However, there was agreement to use Gandhi's model when simulating a worst-case scenario. In his lecture, Gandhi himself presented a head model including the ear. Adapting the electric parameters (dielectricity constant and conductivity) of the material used for the artificial ear, he developed an anatomically realistic model accounting for the distance of 6 mm between mobile phone and head caused by the ear without having to accept - as other models with an artificial ear do - a loss of radiated power by a factor of 2.5 to 3.

Strecker (Wuppertal, Germany) presented an EMF exposure system for cell cultures of the BBB (blood-brain barrier) which was designed with the support of the Research Association for Radio Applications. This system enables us to perform homogenous irradiation of cell cultures with fields of the GSM and UMTS standards. An integrated part of the system is a measurement setup for the determination of the electrical impedance of the cell layer mounted to a filter within the device.



This measurement can be done during exposure without requiring manual intervention thus excluding interferences caused by the measurement itself. The barrier function of the BBB developing in the cell culture analogous to that of the organism can be determined during exposure by measuring the impedance. The circular hollow conductor system parallelly can hold up to 60 individual cultures ensuring a homogenous field exposure for each individual culture. The highly variable power regulation of the radiation source allows for exposure intensities clearly below or above valid SAR limit values. The aim of planned experiments is to clarify effects of EMF on biochemical processes and their mechanisms. To this end, working with cell cultures has a big advantage compared to studies performed in the whole organism. Individual differences between single test animals, as well as stress response caused by the fixation of test animals can be excluded. Since there is no movement, the radiation dose can be exactly defined and measured.

A test for the determination of exposure potentially exceeding limit values was introduced by Neubauer (Salzburg, Austria). A specially developed software containing detailed information on urban area development calculates sites in the vicinity of mobile radio base stations where particularly high radiation levels are expected. Measurements conducted at such sites showed that the valid limit value of 1 mW/m<sup>2</sup> was exceeded in 8 of 13 measurements.

Silny (Aachen, Germany) examined the influence of pulsed (2 Hz, 8 Hz, 217 Hz) and unpulsed EMF (~950 MHz) on cardiac pacemakers over short distances of about 20 cm. The strongest interference was detected at a pulsation of 8 Hz whereas the threshold value for effects of the pulsa-

tion typical for mobile radio of 217 Hz as well as of unpulsed fields was distinctly higher.

Numerical techniques for exposure quantification were presented by Meyer et al. (Stellenbosch, South Africa) and Foster et al. (Philadelphia, USA). Meyer calculated exposure of the human body in the near-field of base antennas; Foster demonstrated a model for the determination of thermal strain in the eye of rhesus monkeys.

A so-called generic UMTS signal was presented by Glasmachers (Wuppertal, Germany). This signal simulates the signal course as is expected during a call made via a UMTS mobile phone for laboratory experiments. The modulation of the UMTS carrier frequency was selected such as to represent all frequency ranges possibly interacting with the biological systems. Thus, a worst-case scenario is simulated.

### **Emerging therapies (session 10)**

In the session dealing with emerging therapies different papers were presented on the application of static magnetic fields and EMF for the treatment of pain, or, in orthopaedics, for bone healing. However, the evaluation of therapeutical effects has not made much progress yet. Though promising results are available, they lack statistical verification. Many of these applications are still in their infancy.

### **Lecture series: In vivo studies – animals (session 11)**

Gatta (Rome, Italy) examined effects of mobile radio exposure of the GSM 900 standard on cells of the immune system of mice (lymphocytes). At an exposure (1 W/kg; 2 W/kg) performed for 2 hs/day over up to 4 weeks, he could not observe any

measurable effect on activation of immune cells and their subpopulations, on proliferation and the release of immunoactivating substances.

The offspring of rats was the focus of the study of Buschmann (Hannover, Germany). Pregnant rats were exposed to GSM radiofrequency from fertilization through the 20<sup>th</sup> day of pregnancy. Exposure at a carrier frequency of 890 MHz, modulation frequencies of 2, 8, 217 and 1733 Hz and a power density of 60 W/m<sup>2</sup> in the cage neither led to alterations in mother animals nor in developing young animals. Sporadic, slight anomalies as often occurred in the test group as in the control group.

According to a study of La Regina (St. Louis, USA), neither in adult animals having been exposed to EMF (835.62 MHz FMCW and 847.74 MHz CDMA) from the 6<sup>th</sup> week of life to the age of 2 years any effects on spontaneous tumor incidence, on survival rate, or on the body weight of the animals could be detected.

Tests performed in mice at exposure to a varying (0.5 to 77  $\mu$ T) 50-Hz magnetic field showed a significant reduction of the number of immune cells. De Jager (Biofontain, South Africa) observed a decrease in the number of lymphocytes in mice after 14-weeks as well as after 12-months of field exposure. Also, the proliferation rate of B- and T-cells was decreased. This study thus confirmed an earlier study of Mevisen.

Seaman (Brooks, USA) investigated movement patterns and startle response of rats following exposure to EMF of 1.25 GHz at a whole-body SAR of 0.6 W/kg, but could not detect any alterations. Exposure was only 30 min, though.

In a study, Shirai (Nagoya, Japan) examined whether mobile phone exposure

can promote tumor growth. In experiments performed in rat liver and in the skin of mice, both with artificially induced tumors, he could not observe any effect on tumor growth promotion compared to non-treated animals (6-weeks exposure of the Japanese PDC standard at 900 MHz or 1.5 GHz; SAR maximum 2 W/kg; 1.5 h/day, 5 days/week). In a similar study, Adey (Loma Linda, USA) even observed a decrease in brain tumor growth in a rat model. Adey used mobile phone fields equalling the American NADC standard (836 MHz) to expose rats for about 2 years at a maximum SAR of 1 to 1.6 W/kg (2 h/day; 4 days/week). An important aspect of this paper was that it considers carrier frequency modulation. Whereas the above mentioned results were obtained using 50-Hz TDMA (time division multiple access), at another modulation type Adey could not observe a decrease in tumor growth.

A contribution of LaGroye (Pessac, France) aiming at confirming that effects of mobile phone exposure (GSM 900 MHz; 0.2 W/kg over 48 h) can be observed and determined in cell cultures. The C6 glioma cell cultures she examined altered their response to induction of an inflammatory mediator (LPS) dependent on the fact whether they were exposed or non-exposed. At exposure to the 900-MHz signal, there was a decrease of 40 % in the release of the enzyme NOS2 playing a part in inflammatory processes. Thus, the mobile radio signal possibly can modify the (in this study artificially produced) inflammatory process.

### **The REFLEX program (session 14)**

A special session dealt with the currently available results of the Reflex project (Risk evaluation of potential environmen-

tal hazards from low energy electromagnetic field exposure using sensitive in vitro methods), a program supported by the EU investigating potential hazards from EMF made up by a total of twelve participating research groups. By coordinating these groups as tightly as possible and by defining experimental standards and measurement proceedings, this project is set to avoid common problems occurring when investigating effects of EMF on biological systems: The extreme variability of experimental setups, the often lacking validation of the biological system, or the problems occurring during quantification of exposure in the sample.

In this session, Rüdiger (Vienna, Austria) described the effects of electromagnetic fields on DNA molecule strand breaks. He could detect an increase in the incidence of single as well as double-strand breaks at 50-Hz intermittent fields beginning with 70  $\mu$ T in human fibroblast cells, but not in lymphocytes. However, these DNA damages did not lead to a reduced viability of the cells. Of particular interest was the finding that the incidence of DNA damages was not only dependent on field strength and exposure period, but also on the frequency at which the field was switched on and off.

Schlatterer (Berlin, Germany) also detected an increased incidence of DNA strand breaks in HL60 cell cultures having been exposed to 1800 MHz (SAR 1 to 1.3 W/kg) over 24 h. Leszczynski (Helsinki, Finland) again claimed that mobile radio exposure can affect gene and protein expression, however without characterizing respective single genes or proteins.

LaGroye (Bordeaux, France) summed up the results found by the Reflex consortium dealing with apoptosis, i.e. controlled cell death. Apoptosis protects the organ-

ism against damages caused by degenerated cells, that is, for example, neurodegenerative diseases or cancer. However, none of the investigations could prove an effect of EMF on apoptosis in human cell cultures.

In his summary, Adlkofer (Munich, Germany) emphasized the need for future research projects giving high priority to the examination of molecular, subcellular and cellular effects of EMF for gaining a better understanding of the relevance of EMF for diseases in the organism.

### **Mary Ellen O'Connor Memorial lecture series / Student lectures**

Besides many studies dealing with non-thermal effects from EMF, Mausset (Montpellier, France) presented an investigation applying high energy fields with a SAR of 4 to 32 W/kg. After short-term exposure of rats (15 min to 2 h to EMF of 900 MHz) Mausset could prove distinct alterations of neurotransmitter concentration, as well as of glia cells, a cell species populating the brain. However, these experiments do not exclude the possibility that the observed alterations resulted from a heating of the rat brain.

Usually, EMF effects on biological systems are subdivided into the categories of thermal and non-thermal effects. Alterations of the system associated with tissue heating are typically thought of as resulting from heating itself. In his posters, Kalns (Brooks, USA) presented studies being of interest in this context. He compared protein expression patterns of rats having been exposed to mm waves (35 GHz; 90 mW/cm<sup>2</sup>) or infrared heating. Both infrared heating as well as field exposure were shown to lead to a heating of the rats, though this heating was inhomogenous.

Out of about 40 upregulated proteins he could find 5 proteins having been upregulated solely by mm waves, not by heating.

For a computerized simulation of thermal effects, Prelewicz (Rockville, USA) introduced prototypes of a program including anatomically realistic models used for dosimetric investigations of RF fields.

### **Plenary session: Epidemiology**

During the session on epidemiology looking at diseases possibly being associated with electric or magnetic fields, none of the lecturers was able to prove such an association. The contributions referred to different studies dealing with cancer risk as well as sleep disturbances and depression.

### **Plenary session: Mechanisms of interaction**

The last lecture series dealt with the mechanisms of interaction between EMF and biological systems. In his contribution on possible hazards from exposure to wireless devices of the so-called third generation, Swicord (Plantation, USA) made clear that risk assessment requires identifying physical mechanisms leading to a response at the biological level. To-date approaches only are able to explain thermal and neurostimulating effects.

But if we seek to explain health-damaging effects, the wide range of non-thermal effects has to be dealt with. Examples of possible biophysical interactions were given by the following lectures. Schiavo (Rome, Italy) dealt with electric dipoles as are found in biological membranes. He elucidated how via the so-called Larmor precession a power transfer from the EM field to dipole molecules can occur. Iwasaka (Tokyo, Japan) described electron transfer in enzymes at EMF exposure. When charge

transfer leads to an alteration of the spatial structure of the enzyme, it could be the basis for a change of the response catalyzed by the enzyme. However, extremely high magnetic field strengths (8 T) are necessary to cause as strong a charge transfer as is required. The concluding lectures dealt with thermodynamic calculations of field effects. These very complex approaches showed that effects on biological processes, at least from a physical perspective, cannot be wholly excluded.

As a first visitor of the BEMS annual meeting, I would like to point to the wide range of methods presented. The meeting gave an overview of worldwide research efforts undertaken in the area of interaction between EMF and biological systems. Here and there, presentations were lost in too much experimental detail, but, surely, this is unavoidable considering the complexity of topics dealt with during the meeting. However, it was rather strange when some author or the other claimed to provide clear evidence for a health-relevant effect based upon a single experimental approach. Instead, an as detailed analysis of molecular interaction between field and biology as possible is required. As soon as we understand alterations of biochemical and genetic processes in single cells caused by EMF, we will be capable to methodically translate them to the whole organism. In-depth basic research at the molecular level will help a lot to obtain valid data needed for risk assessment.

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