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LETTERS TO THE EDITOR

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Reply to A Yu Grosberg's letter to the *Physics – Uspekhi* Editorial Board

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Editorial note
Physics – Uspekhi concludes (at least for the present) the discussion on its pages devoted to the mechanisms of the action of weak electromagnetic and magnetic fields on living systems. It is quite clear that this field of biophysics awaits further experimental and theoretical studies. At the same time, this journal does not place its highest priority on the topics around which the present debate is centered. It is only natural, therefore, to advise the authors to continue the discussion of this problem in special biophysical journals publishing works on the effect of weak magnetic fields and nonionizing radiation on biological systems.

We had recently published in this Journal a review of magnetobiology [1] that provoked critical comment from A Yu Grosberg [2] (hereinafter A G). The aim of the present notes is to show that this criticism is groundless.

(1) A G compares constant and alternating magnetic fields in terms of their potential biological action, which is illogical. The benefit or the harm of radiation depends not only on its nature but also on the conditions and mode of its application, such as the dose range, frequency, duration of exposure, concomitant impacts, and physiological state of a given organism.

(2) The physical nature of biological effects of both low-frequency and microwave fields remains an enigma. Electromagnetic safety standard in different countries vary by a factor of 10 – 1000 depending on the frequency range.

(3) A G places magnetobiology on 'the list of sciences with a compromised reputation' with reference to the book by R Park, *Voodoo Science. The Road from Foolishness to Fraud* [3]. A G maintains that this book confirms the notion that magnetobiologists are incapable of adequately designing an experiment and simply seek to retain financial support for work having doubtful value to society.

It is worth noting that Park does not use the word 'magnetobiology' in his book. One of its chapters is devoted to the discussion of the known hypothesis that electric power lines may have a tumorigenic effect. Park analyzes two or three epidemiological surveys and emphasizes their drawbacks. He tells us in a fictional manner about public concern over some questionable results of epidemiological studies dramatically portrayed by the mass media. Park takes the extreme position, referring the reader only to those epidemiological data that confirm his concept, that is, fail to demonstrate a correlation between the intensity of the background electromagnetic radiation and the prevalence of oncological diseases. He criticizes early and weak works in this field. To strengthen his position, Park cites the opinion of the authors of original epidemiological surveys and their reviewers who, like himself, failed to find any correlation. Meanwhile, opinions differ even there in the United States [4]. It is estimated that if the enhanced background electromagnetic radiation increases the incidence of oncological pathology alone by at least 1%, a country with a population of 50 million might suffer an additional annual loss of nearly 1000 people. In other words, apparently insignificant biological effects may have serious social consequences. Industry and governments in many countries are involved in the clarification of this problem. [1]

(4) Numerous laboratory studies have been conducted, besides epidemiological surveys, that confirm the reality of the phenomenon of nonthermal effects. [2] At the same time, there are numerous experiments showing the biological potency of weak electromagnetic fields, both low-frequency and microwave, that admittedly cause no heating.

(5) Were the existence of nonthermal effects recognized, it would require the revision of not only many previously

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[1] The estimated expenditures of certain developed countries and international organizations on investigations in the field of electro- and magnetobiology are illustrated by the following figures: World Health Organization — \$6 mln in 1996 – 2005; European Commission and national institutes of Sweden, Austria, Finland, Germany, and France — \$20 mln in 1998 – 2002; US Department of Energy and National Institute of Environmental Health Sciences — \$65 mln in 1994 – 1998; US Communal Services Commission — \$7 mln since 1993; US Air Force Research Center — \$5 mln in 2002; studies on electromagnetic dosimetry and cancer in France — 1 mln euros per year; Japanese Ministry of Post and Telecommunications — \$5 mln in 2000 – 2001; Applied Research Council of Denmark and its 'Non-Ionizing Radiation' Project — 4 mln euros in 2004 – 2006, etc. (based on materials from the Internet, 'Bioelectromagnetic Newsletter', and 'Microwave News').

[2] It is difficult to believe that Park, an experienced physicist, was unaware (when he undertook to comment on the situation in 2000) of the results of tens of years of experimental studies in the USA (see, e.g., S Bawin, W Adey, A Liboff, C Blackman, F Prato, T Litovitz). Similar research was carried out and still continues in Russia (N Devyatkov, E Fesenko, O Betskii, Yu Grigor'ev, V Lednev, I Belyaev). The data obtained thus far suggest resonance-like effects from electromagnetic fields.

accepted electromagnetic safety standards but also the very principles that underlie them. The huge costs of such a revision are difficult to estimate. That is why opponents of magnetobiology are so unwilling to surrender, avoiding constructive discussion and having no other recourse but to criticize frankly questionable work.

(6) The authors' area of expertise does not include epidemiological studies; therefore, we cannot make judgments about the correctness of interpretations of their results. Our review [1] was not intended to involve the readers in a dispute over the harm and benefit of electromagnetic fields. The authors wished to demonstrate that nonthermal effects are not in conflict with postulates of general physics. The existence of nonthermal effects should not depend on the results of epidemiological studies.

(7) The quality of experiments in magnetobiology can be questioned only by people swayed by prejudice with no work experience in this field. It is worthwhile emphasizing that the notion of reproducibility is not absolute and needs to be specified in every specific case. This is true not only of magnetobiology but also of all other scientific disciplines. Suffice it to say that physicists are not at all surprised that the results of quantum measurements or photographs of tracks produced by elementary particles vary from one experiment to another. Because different probabilistic processes affect experimental results, the averaging procedure is usually specified in accordance with the nature of these probabilistic processes.

(8) Magnetobiological studies are distinct in that experimental conditions (i.e., a totality of factors essential for the result) cannot be identical in different laboratories largely because the nature of nonthermal magnetobiological effects remains to be elucidated. For this reason, the averaging procedure applied in magnetobiology has not yet been properly defined. In particular, it is not clear how many observations are needed for the averaging. Nevertheless, serious efforts are being made to reproduce nonthermal effects in different laboratories. By way of example, effects of electromagnetic fields on the activity of melatonin (a hormone regulating immunity and the ability of the human body to resist neoplastic processes) were investigated in more than 10 laboratories. Five of them reported statistically significant effects.

(9) There is no sense considering A G's other arguments [2]. Here is only one example. A G writes: "The authors postulate the presence of 30-angstrom or larger vacuum cavities inside protein globules and the possibility of rotation of the molecular group around a pair of exactly co-axial σ-bonds practically without dissipation." This is wrong. The rotation of the molecular group practically without dissipation was not postulated by us but simulated quantitatively on a computer in the framework of the molecular dynamics of the group rotating in the fluctuating low-symmetry potential. 'Exactness of co-axiality' is not needed here. Deviations from co-axiality lead to the appearance of an additional low-symmetry term in the potential. We have discussed the contribution of deviations from the axial symmetry to the interference effect in Refs [5, 6]. Such a perturbation is responsible for the appearance of similar Zeeman multiplets instead of a single unperturbed one which has no effect on interference. Moreover, the localized rotation under consideration is in fact a rotational breather, i.e., one type of localized nonlinear oscillation, the theory of which has been actively developed in the last decade [7, 8]. The absence of marked dissipation for such perturbations can be accounted for by their strong nonlinearity. We apprehend that our model is but the first approximation and needs verification and development in further studies. It should be emphasized that although the theory of interference of angular molecular states does not provide a final solution of the problem, it can be seen as an important step towards this goal.

(10) It was gratifying to learn from our opponent that the theory of interference of angular molecular states is irrefutable. "Can we prove the impossibility of a coherent molecular gyroscope? Probably not... ." There are few theoretically undeniable models of great predictive power. We are aware of only one such model in electromagnetobiology, besides the interference gyroscope, i.e., the Fröhlich model of collective dipole excitations [9]. Proposed more than 30 years ago, it still attracts the attention of researchers [10]. Each new theory has to compete with it to be recognized as being theoretically and practically more relevant to the problem at hand. Even seemingly indisputable theories need to be verified by experiment.

(11) Several decades of thorough studies have not yet brought about an acceptable mechanism of biological effects of weak electromagnetic fields. It is important, however, that they have resolved the apparent paradox of such effects by demonstrating their consistency with known physical laws. This removes the main cause of scepticism on the part of physicists.

(12) We recognize that there are reasons for a cautious attitude to magnetobiology, taking into consideration the difficulty of reproducing laboratory experiments and the lack of convincing epidemiological data; also, there is no generally accepted theory (see, e.g., new books [11, 12]). However, this is not an excuse to wash our hands of the issue; it is a challenge to physicists and biophysicists.

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