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BIOELECTROCHEMISTRY AND BIOENERGETICS

Review

Possibilities and problems of low frequency weak electromagnetic fields in cell biology

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Abstract

In addition to its well-known applications in electroporation of cell membranes, the use of electrostimulation of cellular metabolisms by weak electromagnetic or electric fields as a new tool for the non-invasive penetration of living systems in order to receive new signals from disturbed processes is one of the most interesting topics in bioelectrochemistry. Examples of processes investigated include proliferation, enzyme reactions, biopolymer syntheses and membrane transport. Their responses to direct, capacitive or inductive coupling for stimulation or inhibition occur in regions of positive or negative "electric windows" for frequency, absorbed energy or treatment time, which is illustrated using characteristic examples selected from the literature and from our own results. Of considerable interest is the possibility to electrostimulate reactions — e.g. the phosphorylation of the myosin light chain — in a cell-free system. In this system there is no membrane receiver for electromagnetic energy transformation and hence only a few models — e.g. free radical disturbance — can explain these important results. Literature data obtained at extremely low fields near the thermal noise region sometimes show discrepancies which must be clarified by careful observation of defined physical and biological parameters, e.g. the disturbance by non-coherent electrical noise. Special medical and industrial applications can be developed. This introductory review presents several hints and suggestions for further investigations including environmental "electrosmog".

Keywords: Electrostimulation; Proliferation changes; Cell-free synthesis; Enzyme activation; Biopolymer synthesis

1. Introduction

Since the First World Congress for Electricity and Magnetism in Biology and Medicine, Orlando, FL, 1992 [1], the Second Congress of the European Bioelectromagnetics Association, Bled, Slovenia, 1993 [2], the 16th Annual Meeting of BEMS, Copenhagen, Denmark, 1994 [3], the Fourth International Symposium on Charge and Field Effects in Biosystems, Richmond, VA, 1994, [4] and the 12th International Symposium on Bioelectrochemistry and Bioenergetics, Seville, Spain, 1994 [5] the effects of low frequency (LF) weak alternating electric and electromagnetic fields on cell metabolism have been studied with increasing interest, because electrostimulation has been shown to have a fundamental influence on living systems both in the laboratory and under environmental conditions. Several hundred papers have been published describing phenomena stimulated by direct currents for electric fields E in the mV cm^{-1} range or currents j in the $\mu A\ cm^{-2}$ range induced by microtesla or millitesla magnetic fluxes B. The targets are mainly syntheses, enzymes, second messengers and proliferation processes. Table 1 shows the optimum conditions for electromagnetic stimulations compiled using data from selected papers [6–8]. It can be seen that those conditions generally occur within small regions of f, B, E and j which are known as "electric windows". Moreover, measurements at $B < 0.8$ mT may give unreliable results because of the effect of the geomagnetic field ($B \approx 0.4$ mT).

The aim of this review is to discuss the difficulties involved and possible methods of improving reproducibility, and to describe particular applications of this non-invasive bioelectrochemical tool in the biosciences.

2. Methods

Several types of fields, frequencies and waveforms have been used in medicine and bioelectrochemistry, and three main approaches can be distinguished.

(1) Direct or alternating currents are applied via inert electrodes (platinum, stainless steel, etc.) inserted into cell suspensions, tissues or single cells (microelectrodes): $f <$

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