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SIMULTANEOUS APPLICATION OF A SPATIALLY COHERENT NOISE FIELD BLOCKS RESPONSE OF CELL CULTURES TO A 60Hz ELECTROMAGNETIC FIELD

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L929 murine fibroblasts display a doubling of ornithine decarboxylase activity following 4h exposures to a 60Hz sinusoidal magnetic field of 10 μT. Simultaneous application of a spatially coherent noise field of comparable amplitude eliminated enhancement of ornithine decarbyoxylase activity by the stimulating field. Lowering of the amplitude of the applied noise field restored field-induced enhancement of enzyme activity. These results are discussed in terms of the thermal-noise limit for weak-field detection.

Members of our group have examined the question of the thermal noise limit for detection of weak electromagnetic fields (EMF) by cells (see Litovitz et al., this volume). They reasoned that the spatially random nature of a thermal-noise field is fundamentally different from that of spatially coherent, applied electromagnetic fields, and that this difference could account for the ability of cells to detect weak applied fields without thermal-noise interference. According to this hypothesis, biological response to a stimulating field should be eliminated if a spatially coherent noise field of comparable amplitude is simultaneously applied.

To examine the effects of spatially coherent noise on cellular response to EMF, we have assayed enhancement of ornithine decarboxylase (ODC) activity. Logarithmically growing cultures of L929 cells display a doubling of ODC activity after exposure for 4 h to a 60Hz 10μT magnetic field.[1] ODC response was assessed under conditions in which this stimulating field was applied simultaneously with noise fields of amplitudes equal to or less than that of the stimulating field.

METHODS

Cell cultures were maintained as previously reported.[1] Experiments used three $75cm^2$ flasks of logarithmically growing cells each for control, exposed, and exposed + noise conditions. Stimulating fields (60 Hz, sine wave, 10 μT, induced electric field of 0.04 μV/cm) were applied simultaneously with random-noise fields (spectral range 30-90 Hz; rms amplitude, 0.5-10 μT) via vertically oriented Helmholtz coils. The results are expressed as a ratio of enzyme activities of exposed cultures to those of matched controls, or as the percent of ODC enhancement measured for exposed + noise conditions, relative to that of matched exposed cultures.

RESULTS

Cultures of L929 cells exposed to the 60Hz stimulating field alone displayed an approximately two-fold enhancement of ODC activity (2.10 ± 0.32 times control values). However, simultaneous application of the stimulating field and a random-noise field altered this response (Fig. 1). ODC enhancement was eliminated when the stimulating field was combined with a random-noise field of 10 μT rms amplitude, but as the amplitude of the noise field was diminished to 2 and 0.5 μT, ODC enhancement was restored. ODC enhancement in response to the stimulating field thus depends on the amplitude of the applied noise field.

The ability of spatially coherent noise to interfere with ODC enhancement was examined also for Daudi human lymphoma cells. Preliminary data show that, for this cell line, a maximal enhancement (2.23 ± 0.31) of ODC activity occurred after a 6h exposure to the stimulating field. Addition of a 10 μT noise field to the stimulating field eliminated the enhancement of ODC activity.

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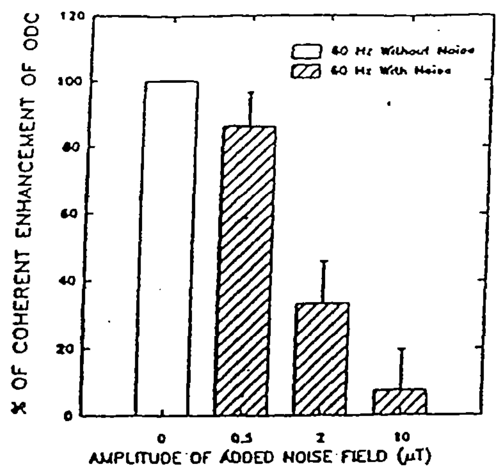

FIG. 1.—Ornithine decarboxylase response of L929 fibroblasts to EMF exposure. Cultures were exposed to 60Hz stimulating field for 4 h with simultaneous application of a spatially coherent noise field of rms amplitude ranging from 0 to 10 μT. Data are expressed as the percent enhancement of ODC activity achieved for exposed + noise samples relative to matched exposed cultures.

DISCUSSION

A spatially coherent noise field, with rms amplitude approximately equal to that of a simultaneously applied stimulating field, inhibited field-induced enhancements of ODC activity in L929 and Daudi cells. The extent of this inhibition depended on the amplitude of the noise field. These data are consistent with the inhibitory effects of spatially coherent noise on field-induced morphological abnormalities in chick embryos (Litovitz et al., this volume). Such similarity in results from work with whole embryos and with cultured cells suggests that the inhibition of field-induced effects by spatially coherent noise represents a general biological response.

Enhancements of ODC activity are thus induced by stimulating fields of microvolts/cm in the presence of random thermal noise fields, but are eliminated by spatially coherent noise fields whose amplitudes are two to three orders of magnitude lower than those of the thermal noise.[2] It is not surprising that cells might ignore the presence of thermal noise fields. Since cells experience the constant presence of random EMF produced by thermal noise, they surely have evolved in ways that render such stimulation inconsequential. The dilemma to be resolved, then, is why applied EMF far weaker than those originating from thermal noise are of consequence in altering cellular response? The concept of spatial coherence elaborated by Litovitz et al. (this volume) provides a hypothesis that answers this question.

It is a reasonable conjecture that many, if not all, effects of EMF on cells occur through interaction of the field with membrane receptor proteins. If that is so, the concept of temporal coherence previously reported,[1] and the requirement for spatial coherence demonstrated here, should provide clues to how fields and receptors may actually interact. In fact, the temporal coherence times we have noted are similar to the times required for aggregation of ligand-bound tyrosine kinase receptors,[3] and the idea of spatial coherence fits with the general concept[4] of receptor cooperativity.[5]

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