

Biological Effects of Electromagnetic Fields

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Abstract Life on earth has evolved in a sea of natural electromagnetic (EM) fields. Over the past century, this natural environment has sharply changed with introduction of a vast and growing spectrum of man-made EM fields. From models based on equilibrium thermodynamics and thermal effects, these fields were initially considered too weak to interact with biomolecular systems, and thus incapable of influencing physiological functions. Laboratory studies have tested a spectrum of EM fields for bioeffects at cell and molecular levels, focusing on exposures at athermal levels. A clear emergent conclusion is that many observed interactions are not based on tissue heating. Modulation of cell surface chemical events by weak EM fields indicates a major amplification of initial weak triggers associated with binding of hormones, antibodies, and neurotransmitters to their specific binding sites. Calcium ions play a key role in this amplification. These studies support new concepts of communication between cells across the barriers of cell membranes; and point with increasing certainty to an essential physical organization in living matter, at a far finer level than the structural and functional image defined in the chemistry of molecules. New collaborations between physical and biological scientists define common goals, seeking solutions to the physical nature of matter through a strong focus on biological matter. The evidence indicates mediation by highly nonlinear, nonequilibrium processes at critical steps in signal coupling across cell membranes. There is increasing evidence that these events relate to quantum states and resonant responses in biomolecular systems, and not to equilibrium thermodynamics associated with thermal energy exchanges and tissue heating. Published 1993 Wiley-Liss, Inc.

Key words: cell membrane, electromagnetic fields, cooperative processes, nonequilibrium thermodynamics, free radicals, athermal interactions

In cellular aggregates that form tissues of higher animals, cells are separated by narrow fluid channels that take on special importance in signaling from cell to cell. These channels act as windows on the electrochemical world surrounding each cell. Hormones, antibodies, neurotransmitters and chemical cancer promoters, for example, move along them to reach binding sites on cell membrane receptors [Adey, 1992a]. These narrow fluid "gutters," typically not more than 150 Å wide, are also preferred pathways for intrinsic and environmental electromagnetic (EM) fields, since they offer a much lower electrical impedance than cell membranes. Although this intercellular space (ICS) forms only about 10 percent of the conducting cross section of typical tissue, it carries at least 90 percent of any imposed or intrinsic current, *directing it along cell membrane surfaces*.

Numerous stranded protein molecules protrude from within the cell into this narrow ICS. Their glycoprotein tips form the *glycocalyx*, which senses chemical and electrical signals in surrounding fluid. Their highly negatively charged tips form receptor sites for hormones, antibodies, neurotransmitters, and for many metabolic agents, including cancer promoters. These charged terminals form an anatomical substrate for the first detection of weak electrochemical oscillations in pericellular fluid, including field potentials arising in activity of adjacent cells or as tissue components of environmental fields.

OBSERVED SENSITIVITIES TO IMPOSED EM FIELDS

As a perspective on the biological significance of this cell-surface current flow, there is evidence from a number of studies that extremely low frequency (ELF) fields in the range 0–100 Hz and radiofrequency (RF) fields amplitude-modulated in this same ELF range, producing tissue gradients in the range 10^{-7} – 10^{-1} V/cm, are involved in essential physiological functions

Received October 14, 1992; accepted October 22, 1992.

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