

# Electromagnetic Fields In Biological Systems

## Biological Effects Of Electromagnetics

Presents recent advances in research on the interactions of electromagnetic fields (EMF) with biological systems. The book discusses the aspects and effects of various electromagnetic fields, as well as the reaction of brain receptor systems to electromagnetic field exposure.

Bioengineering and Biophysical Aspects of Electromagnetic Fields primarily contains discussions on the physics, engineering, and chemical aspects of electromagnetic (EM) fields at both the molecular level and larger scales, and investigates their interactions with biological systems. The first volume of the bestselling and newly updated Handbook of Biological Effects of Electromagnetic Fields, Third Edition, this book adds material describing recent theoretical developments, as well as new data on material properties and interactions with weak and strong static magnetic fields. Newly separated and expanded chapters describe the external and internal electromagnetic environments of organisms and recent developments in the use of RF fields for imaging. Bioengineering and Biophysical Aspects of Electromagnetic Fields provides an accessible overview of the current understanding on the scientific underpinnings of these interactions, as well as a partial introduction to experiments on the interactions themselves.

This book provides readers with comprehensive details on the management and measures to protect health against risks to people and environments generated by the use of ionizing and non-ionizing radiation. This book is divided into three sections, namely, Radiation Protection and Measurement; Radiation Therapy; and Radioactivity. The first section covers ionizing radiation protection; population exposure to non-ionizing density; and the system of dosimetry quantities for use in emergency preparedness and response to nuclear or radiological accidents. The second section covers various planning techniques for spinal stereotactic body radiotherapy and the application of radiation technology in the development of a malaria vaccine. The third section discusses environmental radioactivity monitoring using efficient measurements and the assessment of radiation exposure to humans. Also in this section is the evaluation of the effects of chronic radiation exposure on the testes of mice after a nuclear power plant accident.

Recent concerns over the possible hazards of electrical and magnetic fields in the home and workplace are comprehensively addressed within this book. The chapters contain detailed research on the biological effects of electric and magnetic fields, and evidence for and against any interaction of electromagnetic fields (EMFs) and the biological systems. The relative risk of exposure to EMFs Putative behavioral and neural effects of EMFs EMF effects on cells

The editors are pleased to present these Proceedings of the V Course of the "International School of Radiation Damage and Protection" of the "E. Majorana Centre", held in Erice (Italy) in November 1983. The lectures and discussions among leading scientists in various disciplines of physics, engineering, biophysics, cellular biology, physiology and medicine from 11 countries are included in this compilation. In this volume we have attempted to explore all aspects of the interaction of static and

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Extremely Low Frequency (ELF: 0-300 Hz) electric and magnetic fields with biological tissue, systems and whole organisms; we considered dosimetry and what is known or presumed concerning basic interactions, responses from the cellular and molecular level to the whole organism. Discussions of medical applications as well as epidemiologic investigations related to high voltage transmission were held with critiques of methodologies used and recommendations for future approaches.

Consideration was also given to the necessity and principles of setting protection standards for man and the environment. We believe this is the first attempt to put all this information together into one volume to provide perspective for understanding the influence of static and ELF electric and magnetic fields on biological systems. We hope our attempts were successful. Martino Grandolfo Sol M. Michaelson Alessandro Rindi v  
ACKNOWLEDGEMENTS This is the Fifth Course of the International School of Radiation Damage and Protection of the "Ettore Majorana" Centre for Scientific Culture directed by Professor A. Zichichi.

Through a biophysical approach, *Electromagnetic Fields in Biology and Medicine* provides state-of-the-art knowledge on both the biological and therapeutic effects of Electromagnetic Fields (EMFs). The reader is guided through explanations of general problems related to the benefits and hazards of EMFs, step-by-step engineering processes, and basic results obtained from laboratory and clinical trials. Basic biological mechanisms reviewed by several authors lead to an understanding of the effects of EMFs on microcirculation as well as on immune and anti-inflammatory responses. Based upon investigational mechanisms for achieving potential health benefits, various EMF medical applications used around the world are presented. These include the frequent use of EMFs in wound healing and cartilage/bone repair as well as use of EMFs in pain control and inhibition of cancer growth. Final chapters cover the potential of using the novel biophysical methods of electroporation and nanoelectroporation in electrochemotherapy, gene therapy, and nonthermal ablation. Also covered is the treatment of tendon injuries in animals and humans. This book is an invaluable tool for scientists, clinicians, and medical and engineering students.

This book presents an overview of the field of bioelectricity by demonstrating the biological significance of electromagnetic fields, electrical properties of tissue, biological effects of electromagnetic energy, and therapeutic applications and health hazards of electromagnetic energy.

*Fields, Forces, and Flows in Biological Systems* describes the fundamental driving forces for mass transport, electric current, and fluid flow as they apply to the biology and biophysics of molecules, cells, tissues, and organs. Basic mathematical and engineering tools are presented in the context of biology and physiology. The chapters are structure

Presents a May 1998 World Health Organization (WHO) fact sheet about the physical properties of electromagnetic fields and effects on biological systems.

Dosimetry refers to the calculation and assessment of the radiation dose received by the human body. The proposed book will place emphasis on the existence of physical and biophysical dosimetry. It will be discussed for the proper description and evaluation of the signal at the power generation system. It will cover in detail 10 different parameters of EMF (electromagnetism) exposure such as amplitude, frequency, vector, time of exposure, orientation, etc. In most published papers, these parameters are not

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well defined.

Health Effects of Cell Phone Radiation will offer a concentrated and up-to-date overview on the effects of radio frequencies on human tissue. While significant advances are being made on many fronts, ranging in frequency from quasi-static to the optical regime, a special emphasis of this volume is on current understanding of biological interactions of cellular mobile communication radiation. The use of cell-phones has experienced phenomenal growth - some estimate that there will be more than 3.5 billion users of these wireless devices by the end of 2010, worldwide. The widespread impact of these new wireless technologies has raised concerns about the safety of human exposure to radio-frequency (RF) energy emitted by these telecommunication devices. A better understanding of the biological effects of RF electromagnetic field is needed to safeguard against possible harm to the general population. Fortunately in recent years there has been a resurgence of research interest in achieving a quantitative understanding of the relationships between the biological effects of RF radiation and the physical variables that may cause them. A significant number of results have and are beginning to appear in the literature. This volume reviews and assesses the biological effects of exposure to electromagnetic fields from wireless communication technology.

This book will serve as an ideal guide to the relatively new and complex field of bioelectromagnetics for students and researchers interested in the interaction of biological systems and electromagnetic fields. Coverage details:(1) biological responses of human and animals, both in vivo and in vitro methodologies, to magnetic and/or electromagnetic field exposure, (2) characteristics of effective fields, (3) hypotheses to explain possible mechanisms of interaction between the fields and cells, and (4) induced current in ELF and induced heat in RF fields as key interaction mechanisms.

Spanning static fields to terahertz waves, this volume explores the range of consequences electromagnetic fields have on the human body. Topics discussed include essential interactions and field coupling phenomena; electric field interactions in cells, focusing on ultrashort, pulsed high-intensity fields; dosimetry or coupling of ELF fields into biological systems; and the historical developments and recent trends in numerical dosimetry. It also discusses mobile communication devices and the dosimetry of RF radiation into the human body, exposure and dosimetry associated with MRI and spectroscopy, and available data on the interaction of terahertz radiation with biological tissues, cells, organelles, and molecules.

As wireless technology becomes more sophisticated and accessible to more users, the interactions of electromagnetic fields with biological systems have captured the interest not only of the scientific community but also the general public. Unintended or deleterious biological effects of electromagnetic fields and radiation may indicate grounds for health and safety precautions in their use. Spanning static fields to terahertz waves, *Electromagnetic Fields in Biological Systems* explores the range of consequences these fields have on the human body. With contributions by an array of experts, topics discussed include: Essential interactions and field coupling phenomena, highlighting their importance in research on biological effects and in scientific, industrial, and medical applications Electric field interactions in cells, focusing on ultrashort, pulsed high-intensity fields The effect of exposure to naturally occurring and human-

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made static, low-frequency, and pulsed magnetic fields in biological systems Dosimetry or coupling of extremely low frequency (ELF) fields into biological systems and the historical developments and recent trends in numerical dosimetry Mobile communication devices and the dosimetry or coupling of radiofrequency (RF) radiation into the human body Exposure and dosimetry associated with magnetic resonance imaging (MRI) and spectroscopy Available data on the interaction of terahertz radiation with biological tissues, cells, organelles, and molecules There is great potential for communication, industrial, scientific, and medical use of electromagnetic fields and radiation. To help advance knowledge of the biological effects of such fields and to exploit their potential medical applications, this book highlights critical issues relating to their effects on living systems.

The objective of this book is to present in a concise manner what is actually known at the present time about biological effects of time invariant, low frequency and radio frequency (including microwave) electric and magnetic fields. In reviewing the vast amount of experimental data which have been obtained in recent years, the authors tried to select those results that are, in their opinion, of major importance and of lasting value. In discussing mechanisms of interaction of electromagnetic fields with living matter they have tried to differentiate between what is clearly established, what is suggested by available evidence without being convincingly proven, and what is conjecture at the present time.

The International Symposium on Biological Effects of Magnetic and Electromagnetic Fields was held from September 3-4, 1993 at Kyushu University in Fukuoka . Japan . Originally, it was only intended to be an informal gathering of many scientists who had accepted my invitation to visit Kyushu University after the XXIVth General Assembly of the International Union of Radio Science (URSI), held in Kyoto prior to our symposium . However, since so many distinguished scientists were able to come, it was decided that a more formal symposium would be possible . It was a very productive symposium and, as a result, many of the guests consented that it would be a good idea to gather all the information put forth at the meeting and have it published. In addition, although they were unfortunately unable to attend the symposium . many other distinguished scientists had also expressed their wish to contribute to this effort and, in so doing, help to increase understanding in this, as yet, relatively immature field of science . The question of both positive and negative effects of magnetic and electromagnetic fields on biological systems has become more and more important in our world today as they . Reporting new results, this book covers the subject of biological effects of EMF in its entirety. Experimental verification of the theoretical results is given when at all possible, and the book is expected to open new areas of research, providing material for university course creation.

The past half century has seen an extraordinary growth in the fields of cellular and molecular biology. From simple morphological concepts of cells as the essential units of living matter there has been an ever-sharper focus on functional organization of living systems, with emphasis on molecular dynamics. Thus, life forms have come to be defined increasingly in terms of metabolism, growth, reproduction and responses to environmental perturbations. Since these properties occur in varying degrees in systems below the level of cellular organization, there has been a blurring of older models that restricted the concepts of life to cellular systems. At the same time, a

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search has begun for elemental aspects of molecular and atomic behavior that might better define properties common to all life forms. This search has led to an examination of nonlinear behavior in biological macromolecules, whether in response to electrical or chemical stimulation, for example, or as a means of signaling along a molecular chain, or as a means of energy transfer. Experimental knowledge in this area has grown rapidly in the past decade, and in some respects has outstripped theoretical models adequate to explain these new observations. Nevertheless, it can be claimed that there is now an impressive body of experiments implicating nonlinear, nonequilibrium processes as fundamental steps in sequential operations of biological systems.

Written at the request of the U.S. Air Force and Congress, this book evaluates the potential health effects associated with deployment of the Ground Wave Emergency Network (GWEN), a communications system to be used in case of a high-altitude detonation of a nuclear device. The committee, composed of experts in biophysics, physics, risk assessment, epidemiology, and cancer, examines data from laboratory and epidemiologic studies of effects from electromagnetic fields to determine the likelihood of health effects being caused by the operation of a fully implemented GWEN system.

A broad region of the electromagnetic spectrum long assumed to have no influence on living systems under natural conditions has been critically re-examined over the past decade. This spectral region extends from the superhigh radio frequencies, through decreasing frequencies, to and including essentially static electric and magnetic fields. The author of this monograph, A. S. Presman, has reviewed not only the extensive Russian literature, but also almost equally comprehensively the non-Russian literature, dealing with biological influences of these fields. Treated also is literature shedding some light on possible theoretical foundations for these phenomena. A substantial, rapidly increasing number of studies in many laboratories and countries has now clearly established biological influences which are independent of the theoretically predictable, simple thermal effects. Indeed many of the effects are produced by field strengths very close to those within the natural environment. The author has, even more importantly, set forth a novel, imaginative general hypothesis in which it is postulated that such electromagnetic fields normally serve as conveyors of information from the environment to the organism, within the organism, and among organisms. He postulates that in the course of evolution organisms have come to employ these fields in conjunction with the well-known sensory, nervous, and endocrine systems in effecting coordination and integration.

Recent concerns over the possible hazards of electrical and magnetic fields in the home and workplace are comprehensively addressed within this book. The chapters contain detailed research on the biological effects of electric and magnetic fields, and evidence for and against any interaction of electromagnetic fields (EMFs) and the biological systems. The two volumes cover: \* The relative risk of exposure to EMFs \* Putative behavioral and neural effects of EMFs \* EMF effects on cells

The two volumes of this new edition of the Handbook cover the basic biological, medical, physical, and electrical engineering principles. They also include experimental results concerning how electric and magnetic fields affect biological systems—both as potential hazards to health and potential tools for medical treatment and scientific research. They also include material on the relationship between the science and the regulatory processes concerning human exposure to the fields. Like its predecessors, this edition is intended to be useful as a reference book but also for introducing the reader to bioelectromagnetics or some of its aspects. FEATURES • New topics include coverage of electromagnetic effects in the terahertz region, effects on plants, and explicitly applying feedback concepts to the analysis of biological electromagnetic effects • Expanded coverage of electromagnetic brain stimulation, characterization and modeling of epithelial wounds, and recent lab experiments on at all frequencies • Section on background for setting standards and precautionary principle • Discussion of recent epidemiological, laboratory, and theoretical results; including: WHO IARC syntheses of epidemiological results on both high and low frequency fields, IITRI lab study of cancer in mice exposed to cell phone-like radiation, and other RF studies • All chapters updated by internationally acknowledged experts in the field

This comprehensive and topical volume presents a number of significant advances on many fronts in this area of research, particularly emphasizing current and future biomedical applications of electromagnetic fields.

The book summarizes the emerging topic about the effects of SMF on biological samples ranging from single molecules, subcellular compartments, and cells to whole organisms, as well as the potential application of SMF in clinical treatment of cancer and other diseases. With the development and growing popularity of modern appliances, including MRI in the hospitals, the potential impact of magnetic fields on human health is invoking increasing concerns. At the same time, SMF has been used in the clinical treatment of tumors and other diseases for decades. However, there are still some reservations and uncertainties about these treatments, which are largely due to the differential biological effects reported in the literature. These experimental inconsistencies are mainly caused by variations such as different magnetic field types, intensities, treatment time as well as biological samples examined. This volume will help clarify some dilemmas in this field and encourage further investigations in order to achieve a better understanding of the biological effects of SMF, aiming for a rational application of SMF in clinical therapy in the near future. The book is useful for scientists doctors, and students who are interested in magnetic fields and life sciences.

This reference explores the sources, characteristics, bioeffects, and health hazards of extremely low-frequency (ELF) fields and radio frequency radiation (RFR), analyzing current research as well as the latest epidemiological studies to assess potential risks associated with exposure and to develop effective safety guidelines. Compiles reports

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and investigations from four decades of study on the effect of nonionizing electromagnetic fields and radiation on human health Summarizing modern engineering approaches to control exposure, *Electromagnetic Fields and Radiation* discusses: EM interaction mechanisms in biological systems Explorations into the impact of EM fields on free radicals, cells, tissues, organs, whole organisms, and the population Regulatory standards in the United States, Canada, Europe, and Asia Pacific Evaluation of incident fields from various EM sources Measurement surveys for various sites including power lines, substations, mobile systems, cellular base stations, broadcast antennas, traffic radar devices, heating equipment, and other sources Dosimetry techniques for the determination of internal EM fields Conclusions reached by the Food and Drug Administration, World Health Organization, and other institutions

The growing impact of nonlinear science on biology and medicine is fundamentally changing our view of living organisms and disease processes. This book introduces the application to biomedicine of a broad range of interdisciplinary concepts from nonlinear dynamics, such as self-organization, complexity, coherence, stochastic resonance, fractals and chaos. It comprises 18 chapters written by leading figures in the field and covers experimental and theoretical research, as well as the emerging technological possibilities such as nonlinear control techniques for treating pathological biodynamics, including heart arrhythmias and epilepsy. This book will attract the interest of professionals and students from a wide range of disciplines, including physicists, chemists, biologists, sensory physiologists and medical researchers such as cardiologists, neurologists and biomedical engineers.

A comprehensive and up-to-date collection of papers on the role of electrodynamic activities in biocommunication is presented in this volume. It provides research findings, practical applications and theoretical investigations linking phenomena as diverse as the sensitivity of organisms to ultraweak ELF electromagnetic fields, noninvasive imaging by magnetic field tomography, coherent liquid crystalline mesophases in living organisms and coherent light emission from biological systems. The volume begins with chapters on the historical perspectives and the biophysical background necessary for understanding bioelectrical phenomena. This is followed by chapters dealing with the biological effects of external electromagnetic fields; the detection of endogenous electrodynamic and related activities and their practical applications; and finally, theoretical perspectives and overviews. It is recommended for undergraduates, graduates and research scientists in all disciplines who wish to be informed of the emerging discipline of bioelectrodynamics. List of Contributors: M Bischof, J J Chang, A S Davydov, D Edmonds, A French, C Gross, Q Gu, J Haffeege, M W Ho, A A Ioannides, R P Liburdy, W P Mei, R Pethig, F A Popp, P T Saunders; C W Smith, T Y Tsong, U Warnke, T M Wu, C L Zhang. Contents: The History of Bioelectromagnetism (M Bischof) Electromagnetism and Living Systems (F A Popp) Biological Effects of Weak Electromagnetic Fields (C W Smith) Possible Mechanisms for Biological Effects of Weak ELF Electromagnetic Fields (D T Edmonds) The Language of Cells — Molecular Processing of Electric Signals by Cell Membranes (T Y Tsong & C J Gross) Electromagnetic Fields and Biomembranes (R P Liburdy) Can Weak Magnetic Fields (or Potentials) Affect Pattern Formation? (M-W Ho et al.) Liquid Crystalline Mesophases in Living Organisms (M-W Ho & P T Saunders) Dielectric and AC Electrodynamic Properties of Cells (R Pethig) Dynamic Cell-Membrane Events

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Following the Application of Signal-Pulse Electric Fields (J J Chang et al.)  
On the Biological Nature of Biophotons (W-P Mei)  
Nonsubstantial Biocommunication in Terms of Dicke's Theory (F A Popp et al.)  
Estimates of Brain Activity Using Magnetic Field Tomography and Large Scale Communication within the Brain (A A Ioannides)  
Log-Normal Distribution of Physiological Parameters and Coherence of Biological Systems (C L Zhang & F A Popp)  
Electromagnetic Sensitivity of Animals and Humans: Biological and Clinical Implications (U Warnke)  
Fröhlich's Theory of Coherent Excitation — A Retrospective (T M Wu)  
Energy and Electron Transport in Biological Systems (A S Davydov)  
Bioelectrodynamics and Biocommunication — An Epilogue (M-W Ho & F A Popp)  
Readership: Researchers, graduate and undergraduate students in biophysics.

Keywords: Bioelectromagnetics; Em Hypersensitivity; Bioeffects Of-; Em Fields; Microwaves; Millimetre Waves; Magnetic Flux Quanta; Magnetic Vector Potentials; Electromog; Thermal Effects; Non-Thermal Effects; Sensitivity; Biophotons; Solitons; Nonsubstantial Communication; Fröhlich's Theory; Coherence; Resonance; Electromagnetic-Bioinformation; Magneto-Sensibility; Magneto-Therapy; Electrostimuli; Electro/Magneto-Pollution; Electromagnetic Molecule-Oscillation  
All populations are now being exposed to varying degrees of man-made sources of electromagnetic fields (EMFs) and the exposure levels will likely continue to increase as technological inventions advance. EMFs are thus becoming a major health concern and generate intense debate within the scientific community and in the fellow citizens. Man-made EMFs are currently created mostly by mobile phone communication systems and broadcasting transmitters. Therefore, we provides an overview of the operating principles of electromagnetic field, and discusses the mechanism(s) underlying the effect. Additionally, we review EMF interaction mechanisms with biological systems, deals with the different effects of EMFs.

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