Electromagnetism and Life

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Contents

Preface to Facsimile Edition ix
Preface x
Introduction xii

Part One Historical Developments

1. The Origins of Electrobiology 3

Part Two The Role of Electromagnetic Energy in the Regulation of Life Processes

2. The Physiological Function of Intrinsic Electromagnetic Energy 23
   Introduction 23
   The Nervous System 24
   Growth Control 37
   Bone 48
   Summary 51
   References 52

3. Control of Living Organisms by Natural and Simulated Environmental Electromagnetic Energy 55
   Introduction 55
   Evolution of Life 56
   Biological Cycles 61
   Positional and Navigational Aids 64
   References 68

Part Three Laboratory Studies of the Adaptability of Organisms to Electromagnetic Energy

4. Electrical Properties of Biological Tissue 73
   Introduction 73
   Energy Bands 73
   Piezoelectricity 75
   Superconductivity 78
   Techniques of Application of Electromagnetic Fields 79
   Summary 85
   References 86

5. Effects of Electromagnetic Energy on the Nervous System 91
Introduction 91
Direct Effects 91
Behavioral Effects 96
Summary 99
References 101
6. Effects of Electromagnetic Energy on the Endocrine System 107
Introduction 107
The Adrenal Cortex 110
The Thyroid 111
The Adrenal Medulla and the Pancreatic Islets 112
Summary 113
References 114
7. Effects of Electromagnetic Energy on the Cardiovascular and Hematological Systems 117
Introduction 117
The Cardiovascular System 118
Blood 119
Immune Response 122
Summary 125
References 126
8. Effects of Electromagnetic Energy on Biological Functions 129
Introduction 129
Intermediary Metabolism 129
Reproduction, Growth and Healing 136
Mutagenesis 143
Uncontrolled Variables 145
Summary 148
References 149
9. Mechanisms of Biological Effects of Electromagnetic Energy 153
Introduction 153
Cybernetic Approach 154
Analytical Approach 156
Summary 160
References 163

Part Four Applied Electromagnetic Energy: Risks and Benefits

10. Health Risks Due to Artificial Electromagnetic Energy in the Environment 167
Introduction 167
Levels in the Environment 169
Epidemiological Studies and Surveys 175
Analysis 179
Summary 182
References 182

11. Special Topics Concerning Electromagnetic Energy 187
Therapeutic Applications 187
Acupuncture 188
Impacts on Natural Ecological Systems 191
References 192

Summary 195
Index 197

Preface to Facsimile Edition

In the 1970's we recognized the existence of nonthermal biological effects of electromagnetic energy, and testified to this awareness. One result was the strong opposition of an array of individuals and organizations who tried to command the tide of experimental studies to recede, like King Canute. We attempted to prevent this dispute from coloring our analysis and conclusions in *Electromagnetism & Life*. Hopefully we succeeded.

We intended to present our ideas to a broad range of readers. Our goal was to stimulate and facilitate further research. We made errors in evaluating some studies and theories, as expected in a first attempt to synthesize knowledge from diverse disciplines, but our intentions were honest and we got the most important part of the story correct, so we ask the reader not to judge us too harshly. The book was intended only to be a guide at the beginning of a journey, not a definitive treatise.

I acknowledge a debt to other scientists who also explored the realm of electrobiology, and who left a legacy that has enriched us all. In particular I thank Ross Adey, Carl Blackman, Carl Brighton, Frank Brown, Freeman Cope, Allan Frey, Kjell Hansson-Mild, Yuri Kholodov, Abe Liboff, Aleksandr Presman, Maria Sadchikova, Stephen Smith, Albert Szent-Gyorgyi, and Milton Zaret.

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Preface

The relationship between electromagnetism and life has been a source of fascination and controversy for more than 400 years. Today, interest in all facets of this relationship is at an unprecedented pitch. The body's intrinsic electromagnetic phenomena have been rediscovered, and the evidence suggests that, far from being unimportant byproducts of biochemical activity as previously believed, they play a vital role in diverse physiological processes. The earth has a natural electromagnetic background, produced by the earth itself and by cosmic sources, and the age-old question as to whether this background can be detected by living organisms has now been answered in the affirmative—the earth's electromagnetic background is an important environmental factor for all living things. Clinical uses of electromagnetic energy are increasing and promise to expand into important areas in the near future.

But the coin has another side. The environment is now thoroughly polluted by man-made sources of electromagnetic radiation with frequencies and magnitudes never before present. Man's activities have probably changed the earth's electromagnetic background to a greater degree than they have changed any other natural physical attribute of the earth—whether the land, water, or atmosphere. The evidence now indicates that the present abnormal electromagnetic environment can constitute a health risk.

This book is our attempt to synthesize the various aspects of the role of electricity in biology, and to emphasize their underlying unity. To facilitate this, we divided primary responsibility for the major subject areas. Parts 1 and 2, which treat historical factors and the bioregulatory role of electromagnetic energy, were written by ROB; parts 3 and 4, which deal with bioeffects of artificial electromagnetic energy, were written by AAM. The most apparent effects of electricity—heat and shock—are not treated here. Although there is some interest in the use of electromagnetic hyperthermia in cancer treatment, in general, both phenomena involve well-understood but relatively unimportant physical processes. In stark contrast, subthermal phenomena seem destined to revolutionize the study of biology.

Robert O. Becker, M.D. and Andrew A. Marino, Ph.D., J.D.
Syracuse, New York
1980

Introduction

Over the past decade there has been a growing awareness that electrical and magnetic forces have specific effects on living organisms. These effects are produced by forces of very low magnitude and are not explainable in such simplistic terms as Joule heating. They appear to indicate sensitivities on the part of living organisms several orders of magnitude greater than predictable by present concepts of cellular or organismal physiology.

The effects are apparently separable into two broad categories: those that involve general or specialized functions of the central nervous system (CNS), and those that involve postembryonic growth and healing processes. CNS effects include the production of general anesthesia by electrical currents that traverse the brain, the direction of migratory behavior of the Atlantic eel by the earth's electrostatic field, the navigational aid furnished the homing pigeon by the earth's magnetic field, the apparent cue for the timing of biological cycles by the earth's magnetic field, and the direct relationship between reversals of the earth's magnetic field and the extinction of whole species in the geological past. Growth effects include the alteration of bone growth by electromagnetic energy, the restoration of partial limb regeneration in mammals by small direct currents, the inhibition of growth of implanted tumors by currents and fields, the effect upon cephalocaudal axis development in the regenerating flatworm in a polarity-dependent fashion by applied direct currents, and the production of morphological alterations in embryonic development by manipulation of the electrochemical species present in the environment. This partial list illustrates the great variety of known bioelectromagnetic phenomena.

The reported biological effects involve basic functions of living material that are under remarkably precise control by mechanisms which have, to date, escaped description in terms of solution biochemistry. This suggests that bioelectromagnetic phenomena are fundamental attributes of living things—ones that must have been present in the first living things. The traditional approach to biogenesis postulates that life began in an aqueous environment, with the development of complex molecules and their subsequent sequestration from the environment by membranous structures.

The solid-state approach proposes an origin in complex crystalline structures that possess such properties as semiconductivity, photoconductivity, and piezoelectricity. All of the reported effects of electromagnetic forces seem to lend support to the latter hypothesis.

It is not difficult to conceive of a crystal with self-organizing and self-repairing properties based upon semiconductivity. Signals that indicated trauma would be transmitted by electron flow within the lattice, accompanied by perturbations in the electric field of the crystal. Cyclic patterns of various physical properties would be manifested because of the interaction between lattice electrons and cyclic variations in the external electromagnetic field. Structures of this nature could have been the basis for subsequent organization of complex organic molecules and the gradual acquisition of aqueous-based energetic reactions. Despite the evolved complexity of the solution-based chemical reactions, there would have been no requirement that the solid-state system be discarded, and it could have continued to function into the metazoan state.

Accepting this premise, what characteristics would such a system have today? It would be manifested by an organized pattern of electrical potentials that would alter in a predictable fashion with trauma and subsequent repair processes. It would also be revealed by various types of solid-state properties associated with cells, cellular subunits, and cellular products. It would demonstrate characteristics of a control system, with identifiable input-output and transducer mechanisms. Finally, exposure of the organism to electromagnetic energy would produce alterations in the functions controlled by the system.

In succeeding chapters we present the evidence for this solid-state control system. We begin with the history of our subject because, more than in most areas, it has shaped present attitudes. Against the historical backdrop, one can see the reasons for the delay until the 1970's in the recognition of the true role of electromagnetism in biology.

In chapter 2 we develop the evidence for the existence of a primitive (from an evolutionary standpoint) electrical analog-type data transmission and control system in living organisms. We show that this system resides in the perineural tissue, and that its operation complements the neural control achieved via the action potential.

The value of a new idea lies not only in its ability to explain and coordinate observations, but in the validity of predictions of phenomena based upon it. The concept of living things having intrinsic electromagnetic properties led to the prediction that living things would also respond to external electromagnetic energy—both natural and artificial. This prediction is so at variance with long-accepted concepts that positive confirmation from carefully executed experiments would constitute strong support for the

parent concept. The work described in chapter 3 demonstrates that organisms can receive information about their environment in the form of natural electromagnetic signals, and that this can lead to physiological and behavioral changes.

In the following chapters we review evidence of the biological effects of artificial electromagnetic energy. A large amount of data has been collected regarding the effects of artificial fields upon the nervous, endocrine, cardiovascular, and hematological systems and each of these areas are treated separately. Other reports, not so easily classifiable, are reviewed in chapter 8. Chapter 9 deals with the mechanisms of biological effects of electromagnetic energy.

The conclusion that electromagnetic energy can produce varied and nontrivial biological effects is inescapable. Furthermore, the evidence that such interactions can occur well below the thermal level is similarly inescapable. While this corpus of experimental data constitutes strong support for the theory of the intrinsic bioelectric control system that we present, it also raises new and important environmental questions. Man's power and communications systems utilize extensive portions of the electromagnetic spectrum not previously present in the environment. The effect of this on the public health is discussed in chapter 10.

Knowledge of how living things work from the bioelectric viewpoint is destined to lead to clinical advances. Some present applications of this knowledge are discussed in chapter 11.