

Contents

1. Introduction	1
2. Mechanisms	5
2.1 Introduction	5
2.2 Mechanisms of Interaction with Biological Materials	7
3. Macromolecular and Cellular Effects	19
3.1 Effects on Macromolecules	19
3.2 Effects on Cell Organelles	23
3.3 Effects on Microorganisms	27
3.4 Effects on Somatic Mammalian Cells	29
3.5 Effects on Cell Transformation and Tumor Cells ..	35
3.6 Effects on Cellular Genetics	37
3.7 Summary and Conclusions	38
4. Chromosomal and Mutagenic Effects	40
4.1 Chromosomal Effects	40
4.2 Mutagenic Effects	43
5. Carcinogenesis	46
6. Effects on Reproduction, Growth and Development .	49
6.1 Introduction	49
6.2 Teratogenesis in Species Other Than Mammals ...	49
6.2.1 Fish and Insects	49
6.2.2 Avian Species	52
6.3 Teratogenesis in Mammals	54
6.4 Experimental Studies of Mammals	55
6.4.1 Teratogenesis in the Rat	55
6.4.2 Teratogenesis in the Mouse	59
6.4.3 Observations in Human Populations	64
6.5 Discussion	64
6.6 Summary and Conclusions	66
7. Effects on Hematopoietic and Immune Systems	68
7.1 Effects on Blood and Blood-Forming Organs	68
7.2 Effects on the Immune System	79
7.3 Summary and Conclusions	86

8. Effects on Endocrine System	88
8.1 Introduction	88
8.2 Neuroendocrine and Endocrine Effects	91
8.2.1 Hypothalamic-Hypophysial-Adrenal Response	91
8.2.2 Hypothalamic-Hypophysial-Thyroid Response	99
8.2.3 Growth Hormone	103
8.2.4 Conclusion	104
8.3 Metabolic and Biochemical Effects	104
8.3.1 Neuroendocrine and Metabolic Correlations	106
8.4 Summary and Conclusions	107
9. Effects on Cardiovascular Function	111
9.1 Experimental Findings	111
9.2 Summary and Conclusions	117
10. Interactions with the Blood-Brain Barrier	118
10.1 Introduction	118
10.2 Current Concepts of Anatomy and Function	118
10.3 Pathophysiological Considerations	121
10.3.1 General	121
10.3.2 RFEM Fields and the Blood-Brain Barrier	122
10.3.3 RFEM Fields and the CSF Barrier	130
10.4 Attempted Replications and Extensions of Previous Studies	133
10.5 Discussion	139
10.6 Summary and Conclusions	142
11. Interactions with the Nervous System	145
11.1 Central Nervous System	145
11.1.1 Introduction	145
11.1.2 Observed Biological Sensitivities to Weak Environmental RFEM Fields	145
11.1.2.1 Behavioral Effects of ELF Fields	148
11.1.2.2 Neurophysiological Effects of Modulated RFEM Fields	149
11.1.2.3 Windowed Responses of Calcium-Ion Binding in Brain Tissue to ELF, VHF and UHF Fields	150
11.1.2.3.1 Effects of Sub-ELF and ELF Fields	150
11.1.2.3.2 Effects of Weak VHF and UHF Fields Modulated with ELF	150

11.1.2.3.3	Evidence on the Site and Mechanisms of Transductive Coupling of Fields in Brain Tissue	151
11.1.3	Physiological Models of Weak RFEM-Field Interactions in Tissue	153
11.1.3.1	Quantum Mechanical Models of Long-Range Interactions	156
11.1.3.1.1	Models of Macromolecular Phase Transitions at ELF	156
11.1.3.1.2	Charge "Pumping" and Volterra Models of Charge Population Transitions	158
11.1.3.1.3	Limit-Cycle Models	160
11.1.3.1.4	Tunneling Models	162
11.2	Effects of RFEM Radiation on Peripheral and Isolated Nervous Tissues	163
11.3	Effects of RFEM Radiation on Autonomic Nervous Function	167
12.	Behavioral Studies	169
12.1	Introduction	169
12.2	Methodological Issues	169
12.2.1	Behavioral End Points	169
12.2.2	Behavioral Design	170
12.2.2.1	Respondent Conditioning	170
12.2.2.2	Operant Conditioning	170
12.2.3	Field Parameters	171
12.3	Clinical Investigations	172
12.4	Laboratory Investigations	173
12.4.1	Acute Exposures	173
12.4.1.1	Lethality	173
12.4.1.2	Convulsions	174
12.4.1.3	Work Disturbance	174
12.4.1.4	Endurance	175
12.4.1.5	Perception of RFEM Fields	175
12.4.1.5.1	Human Auditory Perception	176
12.4.1.5.2	Auditory Perception of Pulsed Fields by Small Animals	177

	12.4.1.5.3 Physical Measurements and Mechanisms of Auditory Perception	179
	12.4.1.6 Aversive Behavior	180
	12.4.1.7 Human Cutaneous Perception	181
	12.4.1.8 The Special Case of Work Stoppage	182
	12.4.2 Long-term Exposure	185
12.5	Effects of Prenatal Exposures	187
12.6	Behavioral Thermoregulation	188
12.7	Drug-Field Interactions	189
12.8	Summary and Conclusions	189
13.	Cataractogenesis	191
13.1	Theoretical and Experimental Models	191
13.2	Cataractogenesis in Experimental Animals	195
13.3	Cataractogenesis in Human Beings	203
14.	Studies of Human Beings	207
14.1	Epidemiologic Approach to Investigate Effects of RFEM Radiations	207
14.1.1	U.S. Naval Personnel Occupationally Exposed to Radar	207
14.1.2	American Embassy Personnel in Moscow	211
14.2	Specific Health Effects	214
14.2.1	Ocular Effects	214
14.2.1.1	Minor Lens Changes	215
14.2.1.2	Cataracts	216
14.2.1.3	Retinal Lesions	217
14.2.2	Nervous and Behavioral Effects	217
14.2.3	Congenital Anomalies	219
14.2.4	Cancer	220
15.	Thermoregulatory Responses in Human Beings	221
15.1	Introduction	221
15.2	Fundamentals of Thermoregulation	221
15.2.1	Body Heat Balance	222
15.2.2	Endogenous Heat Production	225
15.2.3	Avenues of Heat Loss	225
15.2.3.1	Vasomotor Control	226
15.2.3.2	Evaporative Water Loss Through Sweating	226
15.2.4	Neurophysiological Control of Thermoregulation	227

CONTENTS / xi

15.2.4.1	Thermosensitive Neural Tissue . . .	227
15.2.4.2	Characteristics of the Thermoregulatory Controller	229
15.3	Limits of Human Heat Tolerance to RFEM Radiation	230
15.3.1	Environmental Variables: Temperature, Vapor Pressure, and Clothing	231
15.3.2	Exercise	233
15.3.3	Febrile States	235
15.4	Thermal Sensation and Thermoregulatory Behavior	236
15.4.1	Thermal Sensations Produced by RFEM Fields	236
15.4.2	Changes in Thermoregulatory Behavior in the Presence of RFEM Fields	238
15.5	Mathematical Models of the Human Thermoregulatory System	239
15.5.1	Characteristics of Models of Human Thermoregulation	240
15.5.2	The Controlled System	241
15.5.3	The Controlling System	241
15.5.4	Performance and Validation of the Model	242
15.5.5	Application of Simulation Models of the Human Thermoregulatory System to Deposition of RFEM Energy in the Body	242
15.6	Supporting Data from Animal Studies	244
15.6.1	Threshold Effects	245
15.6.2	Intense or Prolonged Exposure	248
15.7	Summary and Conclusions	249
16.	Medical Applications	251
16.1	Shortwave Diathermy—Early Clinical Use	251
16.2	RFEM Fields and Oncology—Pioneering Studies of Animals	253
16.3	Thermal-Athermal Controversy	253
16.4	Clinical Dosimetry	255
16.5	Microwave Diathermy and Hemodynamic Effects	258
16.6	Clinical Application of RFEM Fields in Cancer Therapy	259
16.7	Biophysical Characterization of Diathermy	263
16.8	Mode of Action of Diathermy and Therapeutic Indications	264
16.9	Thermal Considerations	268

17. Exposure Criteria and Rationale	271
17.1 Background	271
17.2 Measurement and Units for RFEM Fields	273
17.2.1 Power Density and Field Strengths	273
17.2.2 Dosimetry	274
17.2.2.1 Whole-Body Dosimetry	275
17.2.2.2 Distributive Dosimetry	275
17.2.2.3 Caveats on Interpretation of Dosimetric Measures	276
17.3 Development of the SAR Exposure Criterion	277
17.4 Implementation of Exposure Criteria	279
17.4.1 Occupational Exposure Criteria	279
17.4.1.1 Pulsed or Continuous-Wave (CW) Exposure, Time Averaging for the Occupationally Exposed	281
17.4.2 General-Population Exposure Criteria	282
17.4.3 Time Averaging for the General Population	283
17.4.4 Special Circumstances for Population Exposure	283
17.4.5 Localized Exposure Criteria	284
17.4.6 Mixed-Frequency Fields	285
17.4.7 Modulation	285
17.4.8 Power-Density Peaks	286
17.4.9 Medical Use of RFEM Radiations	286
17.5 Measurements of RFEM Fields	286
17.6 Considerations Possibly Influencing the Criteria in the Future	287
17.6.1 RF Burns and High Localized SAR	287
17.6.2 RFEM Fields and Malignant Tumors	287
References	290
The NCRP	354
NCRP Publications	362
Index	393