0470 NAVY ENVIRONMENT: MECHANISMS OF MICROWAVE-INDUCED BLOOD-BRAIN BARRIER ALTERATIONS. Lin, J. C.; Noonan, S. M. (Wayne State Univ., Sch. Engineering, Dept. Electrical Engineering, 5950 Cass Ave., Detroit, MI 48202).

Microwave fields, such as those emitted by radar equipment, have been shown to alter the blood-brain barrier system in rats. At this time, the mechanisms of this alteration are not known. The objective of this research is to determine the possible interaction mechanisms with the use of biochemical and biophysical analyses. The first phase of this study will be directed toward the biophysical aspects of absorbed energy inside the rat brain. Emphasis will be placed on any direct correlation between absorbed energy and observed alteration in permeability. The second phase will deal with the implications of pulsed microwave-induced thermoelastic displacement of, and stress in, the brain tissue. In addition, any physical manifestations of change as might be seen by electron microscopy of the specific regions of the brain that show permeability changes will be investigated. (funding period 4/78-cont.)

Supporting Agency:U.S. Dept. Defense: Navy, Office Naval Res.

0471 MICROWAVE EFFECTS ON EXCITABLE MEMBRANE SYSTEMS. Cleary, S. F.; Liu, L. (Virginia Commonwealth Univ., Sch. Basic Sciences & Graduate Studies, Dept. Biophysics, 901 W. Franklin St., Richmond, VA 23284).

The excitable internodal cell of the algae *Chara australis* will be exposed to S-band microwave radiation in a temperature-controlled exposure chamber to investigate effects upon the resting potential, amplitude, duration, and propagation velocity of the action potential and the excitation threshold. The independent variables investigated will include microwave frequency, pulse-modulation parameters, field intensity, exposure duration, and temperature. The electrical properties will be measured by the insertion of microelectrodes into the cell external to the waveguide exposure chamber thus eliminating artifacts due to field pick-up or interference. The primary objective of the research is to compare the effects of continuous wave versus pulse-modulated fields on the electrical activity of an excitable cell model of a neuron. The role of field-induced and nonfield-induced temperature increases will also be determined. (funding period 2/78-1/80)

Supporting Agency:HEW, PHS, NIH, Natl. Inst. Environmental Health Sciences

0472 MORTALITY, REPRODUCTIVE AND INDUSTRIAL HYGIENE STUDY OF WORKERS EXPOSED TO MICROWAVES/RADIOFREQUENCY ENERGY. Egan, B.; Cox, C. (U.S. Dept. HEW, PHS, Center for Disease Control, NIOSH, Div. Surveillance Hazard Evaluations & Field Studies, 4676 Columbia Parkway, Cincinnati, OH 45266).

Radio frequency/microwave (RF/MW) radiation has been implicated in a variety of biologic phenomena including altered transmembrane potentials, increased membrane permeability, hyperthermia, hormonal imbalance, chromosomal anomalies, and mutagenesis. Although their exact roles are unknown, similar phenomena have been implicated in carcinogenesis. In addition, several unconfirmed allegations have been made associating exposure to microwave radiation with pancreatic cancer in radar repair workers, brain cancer in electronic workers, and leukemia in the Moscow Embassy employees. Unfortunately, the size of the population potentially at risk in most of these case reports was too small for scientific evaluation. More recent research has indicated that exposure to RF/MW radiation can affect incidence of infertility and teratogenesis among exposed study groups. Further research is required to critically assess both the potential carcinogenic hazards and reproductive hazards of RF/MW radiation. NIOSH has identified a cohort of radar repair workers that may be suitable for inclusion in an epidemiologic mortality study. This population would consist of all persons enrolled in the Electronic Apprenticeship Training Program, which has been sponsored by the Naval Air Reworks Facility since the early 1950's. However, since this study population will only consist of about 1,000 individuals and it may be difficult to obtain complete employment histories on all workers, additional walk-through surveys and record assessments will be conducted in plants having microwave heat sealing, drying, or baking operations before a final cohort is selected. If possible, a cohort will be selected that includes a large number of female employees so that a retrospective cohort mortality study and a reproductive study can be conducted on the same population. If a cohort with a large enough number of female workers cannot be identified, then the wives of male workers will be interviewed for a reproductive history. (funding period 10/77-9/81)

Supporting Agency:HEW, PHS, Center Disease Control, NIOSH

0473 ACCELERATION OF FRACTURE HEALING BY ELECTRICAL FIELDS. Brigton, C. T.; Friedenberg, Z. B.; Black, J.; Pollack, S.; Heppenstall, R. B. (Univ. Pennsylvania, Sch. Medicine, Dept. of Orthopedic Surgery, 36th & Hamilton Walk, Philadelphia, PA 19104).

Investigation of the effects of applied electrical fields on the acceleration of fracture healing in laboratory animals will be continued. The proposed research is designed to determine: (1) the optimum parameters of applied (exogenous) electricity for accelerating fracture healing; (2) the role of stress generated (endogenous) electricity in fracture healing; and (3) the mechanism of elec-

trically induced osteogenesis at the cell level. Methods to be used include the comparison of the osteogenic response of in vitro fetal rat tibia and in vivo healing rabbit fibula to constant direct current, various pulsed unidirectional electric fields, and various electromagnetic fields. Osteogenesis and bone healing will be evaluated by incorporation of tritiated thymidine, ^{45}Ca, and $^{35}SO_4$, as well as maximum resistance to bending as determined by an Instron Testing Machine. Stress generated potentials will be measured in fracture calluses. Origin of stress generated potentials will be evaluated by altering tendon collagen biochemically. The mechanism of action of electrically induced osteogenesis will be sought by determining (1) pO_2 and pH changes in the vicinity of a cathode, (2) changes in surface of cell membrane, (3) mitochondria release of calcium, (4) cellular proliferation and migration, and (5) collagen and proteoglycan biosynthesis and processing. (funding period 8/78-7/79)

Supporting Agency:HEW, PHS, NIH, NIAMDD

0474 COMPARISON OF THEORETICAL AND EXPERIMENTAL ABSORPTION OF RADIOFREQUENCY POWER. Johnson, C. C.; Durney, C. (Utah Higher Education System, Univ. Utah, Sch. Engineering, Dept. Electrical Engineering, 1400 E. 2nd St., Salt Lake City, UT 84112).

Methodology for quantitating electromagnetic radiation (EMR) energy distribution and measurement will be developed. Methods and data are critically needed to extrapolate (via appropriate scaling factors) animal data to man to establish more realistic personnel safety exposure guidelines for Air Force operations. The specific objectives of this study are (1) to define adequate models, (2) to extend theoretic radio frequency (RF) power absorption data to assess consequences of human exposure to 10 kHz to 1.5 GHz RF radiation fields, and (3) to develop methods, accounting for size and orientation effects, to extrapolate animal exposures to equivalent human exposures. Twenty phantoms will be constructed to simulate 3.5 kg monkeys. Absorbed power will be calculated utilizing this monkey model for exposures in free space, near field, and on a ground plane. Experiments will be conducted to measure power absorbed in the phantom and in actual monkeys for six exposure orientations. The best model for man, monkey, rat and mouse will be developed and calculations will be performed to determine power density to which these animals should be exposed to produce the same average absorbed power as man when exposed to 10 mW/cm^2 at the same frequency. The exposure frequency for animals subjected to the same power density as man to accomplish equivalent average power absorption will also be calculated. These data will be used to compile a handbook (Researcher's Guide) for use in selecting appropriate exposure parameters (frequency and power density) for animal studies to simulate bioeffects in man. Power absorption calculations for man and animals will be extended to 1.5 GHz using wave solution, numeric techniques, or other applicable methods. (funding period 1/75-6/80)

Supporting Agency:U.S. Dept. Defense: Air Force, Sch. Aerospace Medicine, Brooks AFB

0475 MICROWAVE EXPOSURE EFFECTS ON BEHAVIORAL ACTIONS OF PHARMACOLOGICAL AGENTS. Thomas, J. R. (U.S. Dept. Defense: Navy, Naval Medical Res. Inst., Behavioral Sciences Dept., Bethesda, MD 20014).

This research will determine if exposure to microwave radiation modifies the effects of pharmacologic compounds on behavior. It is important to determine if microwave radiation interacts with other agents, which may produce potential hazards by changing the efficacy and safety of drugs, medication, and compounds commonly used by military personnel. Initial studies will evaluate how microwave radiation can affect the manner in which organisms react to pharmacologic agents. The research techniques involve the development of complex patterns of behavior in animals. The developed behavioral baselines will be used to assess the effects of both acute and chronic drug regimens under both normal and radiation conditions. Assessment of irradiation effects with low-level microwave energy (near and below 10 mW/cm^2) will be emphasized. Dose-response functions will be determined for a range of radiation intensities for a variety of parameters (frequency, pulse repetition rate, pulse versus continuous wave, acute versus chronic exposure). Using this methodology, modifications in behavior due to interactions between drugs and microwave exposures will be empirically determined. Based on such determinations, re-evaluation of exposure limits for Navy personnel and specific recommendations for drug and medication usage in a microwave environment can be made. (funding period 10/76-10/81)

Supporting Agency:U.S. Dept. Defense: Navy, Naval Medical Res. & Development Command, Natl. Naval Medical Center

0476 A NEW TECHNIQUE FOR ELIMINATION OF CELLS CAUSING DEATH IN BONE MARROW TRANSPLANT PATIENTS. Kessler, S.; Scher, I. (U.S. Dept. Defense: Navy, Naval Medical Res. Inst., Immunopathology Div., Bethesda, MD 20014).

A technique for isolating large numbers of cells belonging to B- or T-lymphocyte subpopulations will be developed. Analysis of the functional and morphologic characteristics of such subpopulations has been hindered by the difficulty in their isolation. However, such analysis is critical to the understanding of the fundamental mechanisms underlying the rejection of allogeneic transplanted tissues, which is the major obstacle to successful

bone marrow transplantation in lethally-irradiated military personnel. The development of these isolation procedures will allow for the depletion of subpopulations of cells involved in graft rejection, without influencing other cellular populations necessary for successful engraftment. Uniform-sized latex (acrylic) microspheres containing colloidal iron will be synthesized. The chemical composition of these microspheres is such that they can be easily complexed with molecules such as specific immunoglobulins and/or fluorescent dyes. Initial studies will be designed to test the overall feasibility of this approach by separation of B- from T-lymphocytes using anti-Ig as the functional probe of the microspheres. A powerful magnetic field will then be used to separate lymphocytes with microspheres attached (B-cells) from unassociated lymphocytes (T-cells). Later studies will utilize reagents prepared to isolate lymphocyte subpopulations known to influence graft rejection. (funding period 10/77-9/79)

Supporting Agency:U.S. Dept. Defense: Navy, Naval Medical Res. Inst.

0477 RADIOFREQUENCY RADIATION MECHANISMS. Smith, G. (Georgia Inst. Technology, Sch. Engineering, Dept. Electrical Engineering, 225 North Ave., N.W., Atlanta, GA 30332).

The mechanisms of radio frequency radiation interaction with living tissue will be studied. A series of mathematical models will be developed describing the physical interaction of electromagnetic fields with tissue structures. The work will involve four levels of complexity in living tissues: (A) molecular physics, (B) details of biomolecular chemical reactions, (C) biomembrane phenomena, and (D) total tissue metabolism. The models will define the frequency dependence of the bioeffects under study, and for a given frequency, the models will suggest whether there is an amplitude threshold and/or window for the effect. For each of the above interactions, presently available models will be critically examined in the light of current theory and experimental data. The critical examination of each model will include a thorough treatment of the underlying physical theories and detailed evaluations of all assumptions. For each interaction, the most promising model(s) will be extended. The extensions can synthesize elements from several models or focus on one model. Available models might be rejected in favor of a new model(s). Various calculations will be performed with particular attention paid to the physical units. (funding period 7/78-12/79)

Supporting Agency:U.S. Dept. Defense: Air Force, Sch. Aerospace Medicine, Brooks AFB

0478 ANALYTIC AND CALORIMETRIC MICROWAVE DOSIMETRY IN THE FAR-FIELD. Olsen, R. G.; Grissett, J. D. (U.S. Dept. Defense: Navy, Naval Aerospace Medical Res. Lab., Medical Science Dept., Pensacola, FL 32508).

The amount and distribution of electromagnetic energy deposited in the human body for a given far-field irradiation intensity at microwave frequencies of particular interest to the Navy will be ascertained. The physical parameters (beam polarization, body posture, and/or ground plane orientation) that produce the worst case energy absorption in the human body will be investigated. Three independent methods will be used in determining microwave absorption. The methods will involve far-field irradiation conditions at or near the frequencies of L-band (1.27 GHz), S-band (2.88 GHz), and C-band (5.67 GHz). First, vector E-fields external to an irradiated phantom will be measured to calculate the net microwave energy absorbed by the target using the difference between incident and scattered energy distributions. Second, a calorimetric dosimetry study will be conducted using nonperturbing temperature probes implanted in man-size and primate phantoms. The phantoms will contain simulated muscle and brain tissue and simulated versions of the major bones of the body. Third, infrared scanning techniques will be used to record surface temperature distributions of live animals and phantom models. (funding period 7/75-9/82)

Supporting Agency:U.S. Dept. Defense: Navy, Naval Medical Res. & Development Command, Natl. Naval Medical Center

0479 LASER EYE MEASUREMENT AND EVALUATION SYSTEM. Bruckner, A. P.; Auth, D. C. (Univ. Washington, Sch. Engineering, Dept. Aeronautics & Astronautics, 206 Guggenheim Hall, Seattle, WA 98105).

This project will develop a system to quantitate eye abnormalities for radio frequency radiation personnel hazard assessment. Specifically, a portable device(s) capable of both holographic recording and short pulse scattering measurements in the eye will be developed. The device is required to quantitate and study radio frequency radiation-induced eye opacities. Previous research resulted in the development of two promising techniques for non-invasive optical evaluation of radio frequency-induced cataracts in the eye in vivo. The first uses short pulse laser rangegating and scattering measurements to determine the thickness of ocular layers. The second records holographically the three-dimensional internal structure of the eye including microcataracts. These techniques will be incorporated into a system that can be used to quantitate eye changes and provide permanent records of such changes. (funding period 9/74-9/79)

Supporting Agency:U.S. Dept. Defense: Air Force, Sch. Aerospace Medicine

0480 SLOW CHANGES IN BLOOD BRAIN BARRIER IN THE RAT FOLLOWING EXPOSURE TO MICROWAVE RADI-

ATION. Gruenau, S. P.; Rapoport, S. I. (U.S. Dept. Defense: Navy, Naval Medical Res. Inst., Behavioral Sciences Dept., Bethesda, MD 20014).

Techniques are being developed at National Institutes of Health for measuring subtle changes in blood-brain-barrier (BBB) permeability in local regions of the brain with a time resolution of 0.5 hr. An absolute sensitivity of 10^{-9} cm/sec, and a standard error of about 20%. This technique has been used to measure BBB permeabilities of glycerol, mannitol, sucrose, and inulin, independent of variations of cerebral blood flow. The technique has demonstrated how long and to what extent microwave radiation induces changes in the BBB. Rats will be exposed to 2,450 MHz pulsed microwave radiation, pulse repetition rate 500 Hz, and 2 μsec pulse duration for a period of 0.5 hr at power densities ≤15 mW/cm^2. At various times following the irradiation, the BBB permeability to ^{14}C sucrose in different parts of the brain will be assayed by the above-described technique. Because animal sacrifice is required for the measurement, different animals will be used for different times. Animals subjected to both sham and experimental radiation will be studied. The time course over days of microwave-induced changes in the BBB permeability will be determined. Future plans include searching for long-lasting BBB changes in animals chronically exposed to about 100 mW/cm^2 at various pulse repetition rates and pulse widths. Irradiation values that cause BBB changes will provide guidelines for the formulation of safe human exposure levels for naval personnel. (funding period 10/77-9/79)

Supporting Agency:U.S. Dept. Defense: Navy, Naval Medical Res. & Development Command, Natl. Naval Medical Center

0481 LOCALIZED ELECTRO-MAGNETIC HEATING. Jones, R. C. (Univ. Arizona, Sch. Medicine, Dept. Radiology, 1501 N. Campbell Ave., Tucson, AZ 85721).

This project is part of a broader program to determine the efficacy of hyperthermia, either used alone or as an adjuvant to radiation or chemotherapy, as a therapeutic modality in the treatment of human malignancies. The proposed research involves a multidisciplinary effort, including biological, physical, and clinical scientists. Specific projects within this program will study a broad-range of the biologic effects of hyperthermia, spanning molecular and biochemical, cellular and organized tissue systems, including both tumor and normal tissues. Other projects will focus on techniques to produce elevated temperature distributions in biologic systems and measure the temperature patterns. The experimental studies will provide the required biologic and physical information required for the initial studies employing hyperthermia in the treatment of human neoplasms. The basic science projects also will further develop the rationale for, and the understanding of, the clinical potential of hyperthermia. The clinical projects will initiate studies to explore the clinical efficacy of hyperthermia, both as a local and systemic modality, combined with radiation or chemotherapy. (funding period 7/78-6/79)

Supporting Agency:HEW, PHS, NIH, NCI

0482 RADIOFREQUENCY RADIATION BIOEFFECTS MATH MODELS. Bell, E. L.; Cohoon, D. K. (U.S. Dept. Defense, Air Force Sch. Aerospace Medicine, Brooks Air Force Base, San Antonio, TX 78235).

Mathematic/computer research adjunctive to laboratory experimentation will be performed to determine the effects of radio frequency radiation on living tissue. The objectives of this research are: (1) to define how radar energy is distributed in the human body and to calculate resultant temperature rises, (2) to quantify acoustic wave generation by pulsed radar and estimate tissue compression responses, and (3) to develop equations describing radio frequency effects on biochemical events including chemical reactions, metabolite diffusion in tissue, and living cell membrane effects. The results will enable prediction of the effects of radio frequency radar on human beings and will improve the quality of Air Force radio frequency radiation safety standards. The use of mathematic/computer formulations will provide estimates of effects presently unavailable through experimentation or direct measurement, improve utilization of available data, and indicate needed critical laboratory tests. To accomplish objectives 1 and 2, the relevant partial differential equations will be solved for specific model living tissues. (funding period 2/78-6/80)

Supporting Agency:U.S. Dept. Defense: Air Force, Sch. Aerospace Medicine, Brooks AFB

0483 NEUROENDOCRINE EFFECT OF PULSED MICROWAVE RADIATION. Lotz, W. G.; Cook, L. L. (U.S. Dept. Defense: Navy, Naval Aerospace Medical Res. Lab., Medical Sciences Dept., Pensacola, FL 32508).

Quantitative measurements of neuroendocrine perturbations induced by microwave radiation will be provided, and the physiologic significance of the neuroendocrine response will be assessed. Neuroendocrine parameters will be measured on rhesus monkeys for both single and chronically repeated exposures. For single exposures the animals will be exposed for 8 hr during a 24-hr period. Hourly blood samples will be drawn by indwelling jugular catheters. Several power levels of exposure will be used to estimate a possible threshold level of exposure required to cause neuroendocrine changes at a particular frequency. When a response has been characterized, the responsive neuroendocrine parameters will be studied during chronically repeated microwave exposures to determine the physiologic significance of the response at a par-

ticular set of field conditions. These experiments will be repeated using different frequencies. (funding period 7/75-9/82)

Supporting Agency:U.S. Dept. Defense: Navy, Naval Medical Res. & Development Command, Natl. Naval Medical Center

0484 VESTIBULO-COCHLEAR EFFECTS OF UHF-MICROWAVE RADIATION. Lebovitz, R. M.; Seaman, R. L. (Univ. Texas, Health Science Center at Dallas, Dept. Physiology, Southwestern Medical Sch., 5323 Harry Hines Blvd., Dallas, TX 75230).

This research will document the effects of microwave radiation (MWR) on the nervous system by examining single unit discharge in sensory systems that are responsive to continuous wave or pulse-modulated MWR. Previous work confirmed that single units in the vestibular pathway and single units in the auditory pathway show an acute response to continuous wave and pulse MWR, respectively. This project will derive a more complete quantitative understanding of these interactions, investigate the underlying physical mechanisms, and evaluate the general biologic significance of these MWR effects in cats. Similar studies using laboratory primates will then follow. The response of single vestibular units and of single auditory units to appropriate physiologic stimuli will be recorded via glass micropipette located in the eighth nerve and in brain stem vestibular and cochlear nuclei. Once functionally identified, the subsequent response of the units of MWR (915 and 2,450 MHz) applied to the head will be noted. For vestibular units, the emphasis will be on their response to physiologic angular acceleration of the head as compared with their response to exposure to near field continuous wave MWR. For auditory unit the emphasis will be on their response to physiologic acoustic stimuli (tone bursts and clicks) as compared with their response to pulse-modulated MWR. The capability of pulsed MWR to mask acoustic stimuli will also be examined. Calibration of the MWR dose will be in terms of regional absorbed energy density. Recording sites will be marked and verified by histologic examination. These data will be applied to the analysis of the biologic hazards of pulsed MWR and of the biomedical utility of MWR interaction with the central nervous system. (funding period 1/78-12/79)

Supporting Agency:HEW, PHS, NIH, Natl. Inst. Environmental Health Sciences

0485 BEHAVIORAL CHARACTERISTICS OF MONKEYS AND RATS IRRADIATED WITH MICROWAVES. Delorge, J. O.; Grissett, J. D. (U.S. Dept. Defense: Navy, Naval Health Res. Center, Biomedical Div., Pensacola, FL 32512).

The effects of low power density microwave radiation on animals will be investigated by measuring ongoing operant behavior in monkeys and rats. Rhesus monkeys, squirrel monkeys, and rats trained on various operant tasks will be exposed for 30 to 60 min periods repeatedly to microwave radiation at low power levels, pulsed at selected frequencies. The animals, while working, will be exposed to far-field radiation at 1.27, 2.45, and 5.64 GHz to demonstrate differential effects of both power density and frequency. Animals will be irradiated in essentially non-reflective restraint devices. In addition, the animals, chosen for body size differences, will perform on similar tasks thereby permitting a comparison of animal size and microwave parameters utilizing operant behavior as the dependent variable. (funding period 7/75-10/82)

Supporting Agency:U.S. Dept. Defense: Navy, Naval Medical Res. & Development Command, Natl. Naval Medical Center

0486 EFFECTS OF ACUTE ELECTROMAGNETIC RADIATION ON THE CENTRAL NERVOUS SYSTEM: MORPHOLOGICAL STUDY OF HYPOTHALAMIC AND SUBTHALAMIC REGIONS. McKee, A. E.; Dorsey, C. H. (U.S. Dept. Defense: Navy, Naval Medical Res. Inst., Experimental Pathology Dept., Bethesda, MD 20014).

The effects of microwave irradiation on the central nervous system (CNS) will be investigated. Morphologic studies of the CNS will be conducted to evaluate and characterize histologic alterations. Efforts will be made to establish thresholds relative to time and power densities and to determine whether morphologic changes are reversible or permanent. Morphologic changes in the CNS of Chinese hamsters due to exposure to acute continuous wave microwave irradiation will be evaluated by light and transmission electron microscopy. Two groups of Chinese hamsters, each divided into two subgroups, will be used in this study. The first group will be irradiated at a frequency of 1.7 GHz and at power densities of 10 and 25 mW/cm^2. The second group will be irradiated at a frequency of 2.45 GHz and at power densities of 10 and 25 mW/cm^2. The exposure time will range from 30, 60, and 120 min. Animals from each group will be sacrificed either immediately after exposure or after a recovery period of 15 days. (funding period 10/77-9/80)

Supporting Agency:U.S. Dept. Defense: Navy, Naval Medical Res. & Development Command, Natl. Naval Medical Center

0487 MICROWAVE-INDUCED DAMAGE IN THE MAMMALIAN BRAIN. Catravas, G. N.; Takenaga, J. (U.S. Dept. Defense, Defense Nuclear Agency, Armed Forces Radiobiology Res. Inst., Bethesda, MD 20014).

Changes in levels of neurotransmitters and activities of enzymes involved in neurotransmitter metab-

olism in the central nervous system of microwave-irradiated animals will be determined. Eastern European studies have indicated that microwave irradiation at low, nonthermal levels results in a number of neurologic and behavioral effects in animals and humans. To substantiate Russian data, a systematic study will be conducted to determine if and to what extent neurochemical mechanisms in mammalian brain are affected by exposure to low level microwave radiation. Groups of rats will be exposed to continuous low-level microwave radiation of 2,450 MHz and approximately 10 mW/cm^2. At various postirradiation time intervals, levels of acetylcholine, norepinephrine, dopamine, and serotonin will be determined in discrete brain areas of experimental animals and sham-irradiated controls. Radiation-induced changes in activity of brain enzymes, choline acetyltransferase, acetylcholinesterase, tyrosine hydroxylase, tryptophan hydroxylase and monoamine oxidase, which are involved in neurotransmitter metabolism, will also be determined. In another series of experiments the effect of microwave radiation on adenylcyclase-cyclic adenosine monophosphate and prostaglandin system will be determined. (funding period 10/76-9/80).

Supporting Agency:U.S. Dept. Defense, Defense Nuclear Agency, Armed Forces Radiobiology Res. Inst.

0488 MICROWAVE EFFECTS. Tredici, T. J. (U.S. Dept. Defense: Air Force, Sch. Aerospace Medicine, Brooks Air Force Base, San Antonio, TX 78235).

A detailed initial ophthalmologic evaluation and follow-up will be provided for Air Force personnel who have suffered a microwave overexposure, i.e., exposure greater than twice the permissible exposure limit. Attention will be focused on the presence or absence of lenticular lesions and the possible causal relation of microwave exposure. Patients will be evaluated in the ophthalmology branch, clinical sciences division, School of Aerospace Medicine at Brooks Air Force Base following standard patient evaluation protocols. Follow-up will be established on an individual basis and reports will be made to the referring physician and medical facility. When sufficient data have been accumulated, the material will be published. (funding period 10/76-12/79)

Supporting Agency:U.S. Dept. Defense: Air Force, Sch. Aerospace Medicine, Brooks AFB

0489 MICROWAVE RADIATION AND THERMOREGULATION. Adair, E. R. (John B. Pierce Foundation of Connecticut, 290 Congress Ave., New Haven, CT 06519).

In recent years, the U.S. research effort in dealing with the biologic effects of nonionizing radiation has increasingly been directed toward the effects produced by low levels of irradiation. These levels have been characterized as having no obvious thermal biologic consequences. This research emphasis has been generated partly by the discrepancy between permitted exposure levels in this country and the Soviet Union and partly by reports from several eastern European countries regarding central nervous system (CNS) malfunctions resulting from prolonged low-level microwave irradiation. If such CNS malfunction could be rigorously demonstrated at any level (from cellular organization to complex behavioral patterns), definitive grounds for reconsideration of the U.S. maximum permissible exposure levels would be provided. The primary goal of this project is to learn whether low levels of microwave radiation can influence or interfere with normal responses, both physiologic and behavioral, that regulate body temperature. The ultimate goal is to evaluate the impact of such disturbances on the human thermoregulatory system with reference to current maximum permissible exposure standards. The research proposed will expose restrained squirrel monkeys to specific durations and intensities of microwave irradiation during ongoing behavioral thermoregulation and during measurement of autonomic responses of heat production and heat loss at a variety of discrete ambient temperatures. (funding period 9/77-9/79)

Supporting Agency:U.S. Dept. Defense: Air Force, Office Scientific Res.

0490 USE OF SYNAPTOSOMES AS AN EXPERIMENTAL MODEL FOR EVALUATING THE EFFECT OF ELECTROMAGNETIC RADIATION (EMR) ON NEURAL MEMBRANE FUNCTION. Millar, D. B.; Christopher, J. P. (U.S. Dept. Defense: Navy, Naval Medical Res. Inst., Biochemistry Div., Bethesda, MD 20014).

Synaptosomes will be used as a neural membrane model to evaluate the potential hazard that electromagnetic radiation (EMR) poses to military personnel during performance of critical, defense-related tasks. Synaptosomes will be prepared from guinea pig brains and purified by density gradient centrifugation. Neural membrane function will be reflected by changes in the permeability of isolated synaptosomes. Permeability will be monitored by the uptake of radiolabeled choline, release of radiolabeled calcium, and by the measurement of internal membrane viscosity with appropriate fluorescent probes. The results will serve as baseline values for permeability in the absence of EMR. Synaptosomes will then be exposed to radiation of various doses with a frequency of 2.8 GHz (radar). Power levels will be determined as specific absorption rates, and proper thermal controls will be employed in each case. Threshold values for EMR-neural membrane interaction will be determined in this manner. Neuropharmacologic drugs will then be screened for those that minimize the effect of EMR on the stability of synaptosomes. (funding period 10/77-9/82)

Supporting Agency:U.S. Dept. Defense: Navy, Naval Medical Res. & Development Command, Natl. Naval Medical Center

0491 EFFECTS OF MICROWAVE RADIATION ON THE BEHAVIORAL DEVELOPMENT OF LEARNING PROCESSES: ACUTE AND CHRONIC EXPOSURE. Maitland, G.; Thomas, J. R. (U.S. Dept. Defense: Navy, Naval Medical Res. Inst., Behavioral Sciences Dept., Bethesda, MD 20014).

The overall objective of this research is to determine whether acute and chronic exposures to low power levels of microwave radiation produce effects on the acquisition of new behaviors. It is important to determine whether the learning process is modified by microwave radiation levels similar to those produced by the electromagnetic emitting equipment operated by naval, surveillance, and communication systems. Acquired behavior is weaker and more susceptible to environmental influences than maintained well-established behavior. Established effects of low-level radiation on the development of behavior can be used to aid in specification of permissible levels of exposure across a range of frequencies for military personnel under functionally similar conditions. The methodology involves several new behavioral techniques that have been developed for studying repeated acquisition of behavioral chains with individual subjects. These techniques, which have proved to be extremely sensitive to the effects of a range of environmental variables, will be used to measure low-level radiation effects on behavior acquisition in animals as modified by several important radiation parameters. Frequency (initially 1 to 3 GHz), modulation values, and exposure time will be explored. Acute exposures as well as continuous exposures under chronic conditions (up to 90 days) will be emphasized. (funding period 10/77-10/82)

Supporting Agency:U.S. Dept. Defense: Navy, Naval Medical Res. & Development Command, Natl. Naval Medical Center

0492 LOW LEVEL MICROWAVE RADIATION EFFECTS ON BEHAVIOR. Thomas, J. R.; Yeandle, S. (U.S. Dept. Defense: Navy, Naval Medical Res. Inst., Behavioral Sciences Dept., Bethesda, MD 20014).

The effects of low-level microwave radiation on behavior will be determined. Behavioral changes produced by radiation will be used to establish threshold power levels and may be used both in determining low-limit permissible levels for naval personnel exposure and in reevaluating acceptable exposure limits. Operant conditioning techniques will be used to develop complex timing, counting, and perceptual-motor behaviors in animal subjects. Such baselines will be used to assess irradiation effects with low-level microwave energy (near 10 mW/cm^2). Lower-limit threshold radiation values that cause detectable behavioral changes will be established by assessing a range of frequencies and modulation parameters. As specific behavioral effects are established, additional studies will investigate concurrent effects and interactions of microwave irradiation on behavioral changes. Long-term chronic exposures will be conducted to determine any possible cumulative behavioral effects. The irradiation values that cause any specific behavioral changes may be used for studies to establish lower-limit permissible values for human exposure. (funding period 7/74-10/80)

Supporting Agency:U.S. Dept. Defense: Navy, Naval Medical Res. & Development Command, Natl. Naval Medical Center

0493 NAVY ENVIRONMENT: MICROWAVE DISPERSION AND ABSORPTION IN TISSUE: MOLECULAR MECHANISMS. Foster, K. R. (Univ. Pennsylvania, Sch. Engineering & Applied Sciences, Dept. Bioengineering, 4001 Spruce St., Philadelphia, PA 19104).

This research is part of the Navy's ongoing program to elucidate the basis for alterations in biologic tissue resulting from microwaves and other electromagnetic fields. This research specifically seeks to increase the data base relating to the dielectric permittivity of tissue on a macroscopic and microscopic level. The dielectric properties of various tissues over the frequency range of 0.1 to 18 GHz will be examined. Measurements will be made by confining the sample in a coaxial line or waveguide section that is terminated in a known impedance. Using a slotted line, the standing wave pattern in front of the sample will be measured allowing calculation of the dielectric properties of the material. Special emphasis will be placed on bound and free water. Molecular mechanisms that result in microwave absorption will be studied as functions of frequency and temperature. (funding period 4/78-cont.)

Supporting Agency:U.S. Dept. Defense: Navy, Office Naval Res.

0494 ELECTROMAGNETIC BLOOD WARMING. Silva, J.; Bentley, B. K. (U.S. Dept. Defense: Navy, Naval Ocean Systems Center, Systems & Technology Dept., San Diego, CA 92152).

The feasibility of using electromagnetic energy to thaw frozen blood products for clinical use in the Navy will be determined. The use of energy at different frequencies from approximately 30 to 3,000 MHz will be explored to determine the optimum wavelength for this application. Initial tests will be performed using materials with dielectric properties similar to those of frozen blood. Heat transfer properties and temperature elevation profiles, as functions of frequency and energy level, will be determined. Subsequently, tests using genuine frozen blood products will

be performed. Finally, a test protocol for handling electromagnetically thawed blood will be prepared and followed to establish the value of the method of heating as a means of restoring frozen blood to its clinically useful form. (funding period 10/76-10/79)

Supporting Agency:U.S. Dept. Defense: Navy, Naval Medical Res. & Development Command

0495 BIOLOGICAL EFFECTS OF LOCALIZED ELECTRIC AND MAGNETIC MICROWAVE FIELDS. Olsen, R. G.; Grissett, J. D. (U.S. Dept. Defense: Navy, Naval Aerospace Medical Res. Lab., Medical Sciences Dept., Pensacola, FL 32508).

The effects of individual microwave fields on small biologic systems will be studied. Both the E-field and H-field exist in a traveling plane wave; however, when such a wave is reflected from a flat conducting surface, a standing wave pattern is formed creating regions of predominantly one field quantity or the other. Since standing waves are found on board ship because of reflections from bulkheads, other conducting structures, and equipment, it is important to determine whether there are specific biologic effects of exposure to one field quantity or the other. A two-dimensional standing wave pattern will be generated at 5.95 GHz by wave reflection from a metal plate at normal incidence. Pupae of the darkling beetle, *Tenebrio molitor*, will be placed in regions of the standing wave that contain predominantly only one field component. Microwave energy that has been deposited in the pupae will be measured calorimetrically using both miniature temperature probes during irradiation and post-irradiation cooling curves. Infrared scanning techniques will be used to determine the spatial distribution of the absorbed microwave energy. (funding period 5/75-9/81)

Supporting Agency:U.S. Dept. Defense: Navy, Naval Medical Res. & Development Command, Natl. Naval Medical Center

0496 COMPUTER STUDIES OF DOSE DISTRIBUTION IN BIOLOGICAL MODELS EXPOSED TO ELECTROMAGNETIC RADIATION. Meijer, P. H. (Catholic Univ. America, Sch. Arts & Sciences, Dept. Physics, 620 Michigan Ave., N.E., Washington, DC 20017).

Theoretic dose distribution calculations for man exposed to nonionizing electromagnetic radiation will be performed utilizing newly-developed computer programs. Theory and programs have been perfected using finite element numeric approximation techniques for the calculation of induced fields and power deposition in biologic tissue of two-dimensional geometry and irregular cross sections. (funding period 9/77-4/79)

Supporting Agency:HEW, PHS, FDA, BRH

0497 RADIOFREQUENCY RADIATION INTERFERENCE (RFI) OF MEDICAL PROSTHETIC DEVICES. Mitchell, J. C.; Hardy, K. A. (U.S. Dept. Defense: Air Force, Sch. Aerospace Medicine, Brooks Air Force Base, San Antonio, TX 78235).

A biomedical data base on the interaction of Air Force radio frequency (RF) radiation emitters and medical prosthetic devices will be established, and a state-of-the-art technology watch on cardiac pacemaker interference will be maintained. Manufacturers' progress in developing pacemakers to operate properly in pulsed RF fields of 200 root mean square V/m will be assessed, and the data will be applied to operational situations in accordance with Air Force regulation (AFR) 161-42. New state-of-technology pacemakers will be accepted on loan from manufacturers and evaluated under a variety of RF emission sources in the USAFSAM laboratory. Sources will include radio frequencies between 50-500 MHz. Field tests will also be conducted using a high frequency transmission system. Additional field tests will be conducted in support of specific operational problems as provided by AFR 161-42. (funding period 7/74-6/79)

Supporting Agency:U.S. Dept. Defense: Air Force, Sch. Aerospace Medicine, Brooks AFB

0498 RADIOFREQUENCY RADIATION EFFECTS ON BIOCHEMICAL SYSTEMS IN THE CENTRAL NERVOUS SYSTEM. Merritt, J. H.; Frazer, J. W. (U.S. Dept. Defense: Air Force, Sch. Aerospace Medicine, Brooks Air Force Base, San Antonio, TX 78235).

The Department of Defense Triservice Electromagnetic Radiation (EMR) Bioeffects Research Program describes the central nervous system (CNS) as the "singularly most important area where there is evidence that EMR interacts with biological systems." The objective of this effort is to quantitate the radio frequency (RF) EMR effects on biochemical events subserving nerve transmission in the CNS. The information obtained will be applied to establish more appropriate safety standards for personnel working in close proximity to Air Force RF emitters. The effects of RF radiation on the CNS, specifically on a specialized function of the neuron, namely synaptic transmission, will be studied. This effort will attempt to quantify changes produced by RF energy in these chemical switching systems, determine thresholds for frequency and power density, and interpret these changes in terms of the expected effect on man in Air Force operational environments. (funding period 9/74-8/79)

Supporting Agency:U.S. Dept. Defense: Air Force, Sch. Aerospace Medicine, Brooks AFB

0499 FLUID SHEAR OF MAGNETIC ALIGNMENT OF BLOOD COMPONENTS. Gardner, R. A. (Washington Univ., Sch. Engineering & Applied Science, Dept.

Mechanical Engineering, 4559 Scott Ave., St. Louis, MO 63130).

The objective of this project is to quantitatively identify field mechanisms of interaction in blood due to either fluid flow (rate-of-shear) or externally applied fields (electric or magnetic). Two effects, which have been recently documented are the delay of in vitro thrombus formation due to either increasing rate-of-shear in the flow or the application of an external magnetic field. The results of this research may validate the hypothesis that the mechanism that results in these effects is the preferential alignment of one or more of the macromolecular participants in the in vitro thrombus-formation process. Fresh whole blood (wb) or platelet-rich-plasma (prp) from fasted normal donors will be used to produce coagula under the controlled in vitro flow conditions of a modified Chandler rotating loop system. The effects to be studied include: (a) the dependence of thrombus-formation time in prp and wb on field strength and rate-of-shear, and (b) the dependence of thrombus structure in wb and prp on field strength and rate-of-shear. The reduced sedimentation of erythrocytes in whole blood or single protein solutions in a transverse field will be examined theoretically and experimentally to identify orientation effects. Solutions of single blood proteins will be examined using the optical techniques of spectrophotometry, spectropolarimetry, and birefringence to quantify their orientation in a transverse magnetic field. (funding period 6/77-11/79)

Supporting Agency:HEW, PHS, NIH, Natl. Heart Lung & Blood Inst.

0500 EFFECTS OF MICROWAVE RADIATION ON NEURAL RESPONSE AND THE CENTRAL NERVOUS SYSTEM. McRee, D. I. (Natl. Inst. Environmental Health Sciences, NIH, PHS, HEW, P.O. Box 12233, Research Triangle Park, NC 27709).

Isolated nerve preparations will be exposed to different microwave frequencies, intensities, and modulations to determine whether microwave radiation has a direct effect on nerve function. One possible site of interaction may be the neuronal membrane since it plays an important role in maintaining the ionic gradients that are necessary for the propagation of electrical impulses. Preliminary experiments have shown that microwave irradiation causes a faster rundown of nerves that are continuously stimulated. These experiments will be continued to determine whether microwaves have a direct effect on membrane permeability to cations. (funding period n/a)

Supporting Agency:EPA, Office of Energy, Minerals, and Industry

0501 EFFECTS OF 2450 MHz MICROWAVES ON THE EMBRYONIC DEVELOPMENT, IMMUNOLOGY AND FERTILITY OF JAPANESE QUAIL. McRee, D. I. (Microwave Res. Section, Natl. Inst. Environmental Health Sciences, NIH, PHS, HEW, P.O. Box 12233, Research Triangle Park, NC 27709).

The effects of microwave radiation on embryonic development, immunology, and fertility of the mature quail were studied in quail exposed to microwaves during their development. Fertilized Japanese quail eggs were exposed to 2,450 MHz microwave radiation at incident power density of 5 mW/cm^2 for the first 12 days of embryogenesis. The eggs were then transferred to a regular hatching incubator until hatch (17 days). Control eggs were treated exactly the same way except for the microwave exposure. At hatch the quail were checked for deformities. No differences were found in the hatchability or development in the controls and exposed quail. The quail were then placed in regular feeding and housing facilities and were not exposed to any microwave radiation after hatch. Reproductive performance in the quail was monitored from 6 through 22 wk of age. Nonexposed controls of both sexes, as well as exposed females, performed normally. However, the exposed males had reduced sperm numbers and reduced sperm motility, and there was a decreased percentage of fertile eggs produced by control or exposed females when paired with exposed males. Mating behavior was normal in both exposed and nonexposed males. (funding period n/a)

Supporting Agency:HEW, PHS, NIH, Natl. Inst. Environmental Health Sciences

0502 BIOMEDICAL EFFECTS OF MAGNETIC FIELDS. Rubias, C. A. (Lawrence Livermore Lab., Univ. California, P.O. Box 808, Livermore, CA 94550).

A variety of magnetic exposure devices will be developed for exposure of biologic materials and humans to controlled field distribution with other environmental variables under rigid control. Basic effects on cells and molecules will then be measured. Certain types of suspected effects, especially visual and nervous system effects, will be investigated in mammals and man. These devices should permit the establishment of a basic relation between field intensity, spatial and temporal variations, and biologic effects; remove the existing controversial and confusing information that exists; and permit recommendations for safe operation of future power systems. Initial assessment of effects should be available by July 1979. (funding period n/a)

Supporting Agency:U.S. Dept. Energy, Div. Biomedical and Environmental Res.

0503 ELECTROMAGNETIC RADIATION PRODUCT INVESTIGATION AT RADIO-FREQUENCIES. Ruggera, P.

S. (Electronic Products Div., BRH, HEW, 5600 Fishers Lane, Rockville, MD 20852).

Three classes of radio frequency (RF) emitting products, investigated in light of their potential for significant impact on public health through direct radiation emission or through interference to critical life support equipment are currently being studied. The electric and magnetic strengths from industrial RF sealers, citizen-band radios, and electrosurgical units have been quantified utilizing state-of-the-art instrumentation developed by BRH in previous years. Preliminary investigations have confirmed that under typical use conditions, these products can exceed the applicable safety exposure standards set by the American National Standards Institute, and/or could severely affect the function of critical equipment through electromagnetic interference. Through cooperation with other involved governmental agencies and manufacturers, BRH will define and attempt to minimize the potential hazard through technical and regulatory activities. (funding period n/a)

Supporting Agency:HEW, PHS, FDA, BRH

0504 BIOPSYCHOLOGICAL STUDIES OF MICROWAVE IRRADIATION. Justesen, D. R. (Dept. Psychiatry, Sch. Medicine, Univ. Kansas, 39th St. and Rainbow Blvd., Kansas City, KS 66103).

A behavior-development-longevity study of C3H mice that were sham radiated or microwave radiated in utero (3 exposures between days 9 and 15 of gestation: 2.45 GHz at 60 Hz sine modulation, 43 mW/g whole-body dose rate for 20 min in multimode cavity, dams' LD_{10}) is in progress. In the first 12 mo, the following observations were made: (1) mortality of radiated pups of surviving dams was higher than that of controls, but there was little difference in death rates of weaned animals; and (2) indices of development (e.g., eye-opening latency, growth of pelt, and body mass) were essentially the same for radiated and control animals. Of particular interest in the coming months will be differences of longevity of animals and of rate of development of spontaneous tumors. (funding period n/a)

Supporting Agency:HEW, PHS, FDA, BRH

0505 BIOPSYCHOLOGICAL STUDIES OF MICROWAVE IRRADIATION. Justesen, D. R. (Neuropsychology Res. Lab., VA Hosp., 4801 Linwood Blvd., Kansas City, MO 64128).

Ongoing studies of longevity and development of tumor-prone mice, whose dams were subjected to LD_{10} radiation, are entering the second yr. To date, little has been found behaviorally to distinguish radiated from control mice. The incidence of spontaneous tumors is nil in both groups, but close monitoring will be continued. Nearing completion is a study in which rats are being observed for evidence of escape learning during trials in an intense 918-MHz field. While marked behavioral and physiologic signs of overheating are observed, there is no evidence of purposive escape. Diffuse whole-body heating, lack of directional cueing, is believed responsible. (funding period n/a)

Supporting Agency: U.S. VA, Dept. Medicine and Surgery

0506 BOSE-EINSTEIN CONDENSATION IN BIOLOGICAL SYSTEMS. Wu, T. (State Univ. New York, Binghamton Campus, Sch. Science & Mathematics, Dept. Physics, Vestal Parkway East, Binghamton, NY 13901).

Frohlich's model suggests that energy applied above a critical rate to the branch or branches of biologic systems that contain dipolar elements capable of oscillation causes Bose-Einstein condensation into the lowest energy state. Several recent Soviet experiments, involving microwave irradiation of living organisms, provide strong support for Frohlich's theory. A criticism of Frohlich's theoretic model will be analyzed, and an alternative microscopic approach using perturbation theory will be examined. This research project will involve the Green's function method. By this theoretic technique the lifetime of the collective excitations in the biologic system will be calculated and will yield an approximate value for the time representing the onset of the coherent oscillation of the dipole elements in certain biologic systems. Finally, the research will deal with model studies where at first simple, specific biologic systems will be analyzed. The interplay of theory and experiment will yield better physical models and closer correlation between theoretic predictions and experimental measurements. (funding period 2/78-2/80)

Supporting Agency:HEW, PHS, NIH, Natl. Inst. General Medical Sciences

0507 RADIOFREQUENCY ELECTROMAGNETIC ENVIRONMENT SIMULATION AND MEASUREMENT. Allen, S. J. (Sch. Aerospace Medicine, U.S. Dept. Defense, Brooks Air Force Base, San Antonio, TX 78235).

The equipment and methodology necessary to define radio frequency (RF) energy transfer to animals and man will be developed. The results of these experiments will provide the basis for modifying the personnel exposure criteria for Air Force RF operations. Instrumentation will be developed to monitor incident fields and absorbed power for biologic systems exposed to RF fields in the range of operational Air Force systems, 10 MHz-10 GHz. The present power absorption techniques are usable from 10 to 50 MHz.

Methodology will be developed to measure power absorption in the 50 MHz-10 GHz frequency range. The modeling of animals will continue until a suitable model for the theoretic analysis necessary to predict power absorption over the specified frequency range is found. (funding period n/a)

Supporting Agency:U.S. Dept. Defense: Air Force, Sch. Aerospace Medicine, Brooks AFB

0508 IONIZING AND NON-IONIZING RADIATION BIOLOGY. Appleby, A. (Agricultural Experiment Station, New Brunswick Campus, Rutgers--State Univ. New Jersey, Old Queens Bldg., New Brunswick, NJ 08903).

An understanding of the biologic and chemical processes involved in the interaction of radiation with organisms will be sought to enable the development of ways to inhibit, neutralize, or reverse the biologic damage caused by radiation. The relative radiation sensitivity of experimental animals with or without treatment by radiated gas will be determined by standard procedures. A 2,450 MHz microwave oven was calibrated by colorimetry as a specimen irradiator, and its effects on mouse thyroid function were examined. Preliminary results showed no significant changes in thyroid function following single or multiple exposures at various power levels. The effects of chronic low level microwave exposures on cataract formation of the anterior lens of mammals of various ages will also be evaluated. The mitotic index of the chosen species will be measured by tritiated-thymidine autoradiography in different age groups after various exposure periods, and followed by observing cataract producing doses. (funding period 7/71-6/81)

Supporting Agency:New Jersey State Government

0509 MEASUREMENT OF MUSCULATURE BLOOD FLOW INDUCED BY MICROWAVE DIATHERMY. Lehmann, J. F. (Medical Rehabilitation Res. and Training Center, Univ. Washington, 15th Ave. N.E., Seattle, WA 98105).

To ascertain the quantitative relation between microwave diathermy and deep musculature blood flow increases and rate changes, a ^{133}Xe-washout technique of the human thigh will be utilized. Prior to the actual isotope wash-out experiments, however, subjects will be familiarized with the general experimental procedures and X-rays of both thighs from the lateral aspect will be taken to determine the anatomic dimensions relevant to the thigh diathermy problem (i.e., thicknes of the anterior fat layer, location of the femur relative to the anterior thigh surface, and the distortion of the thigh profile). The geometric dispersion of the injected ^{133}Xe depot will be imaged by means of a gamma ray camera interfaced with an on-line computer having disk memory allowing replay of the depot clearance event and separate analysis of different regions in time and space. The thigh blood perfusion rate will be quantitated by coupling the wash-out image with the ^{133}Xe clearance measurement by means of a scintillation counter. In addition, the microwave diathermy process, comprising both the absorbed energy distribution and the responding blood flow field, will be modeled with a finite element digital computer thermal analyzer to define the range of most probable models describing the physiologic response of the thigh. This computer model will consolidate information from (a) previous and ongoing tissue substitute model energy deposition experiments, (b) transient human thigh temperature data obtained in vivo during diathermy application, (c) anatomic details regarding the thigh's geometric distortion under the weight of the direct contact diathermy applicator (obtained from cadaver specimens), and (d) the ^{133}Xe blood clearance experiments. (funding period 8/76-8/80)

Supporting Agency:HEW, Office of Human Development Services, Rehabilitation Services Admin.

0510 IMMUNOLOGICAL ASPECTS OF HYPERTHERMIA CANCER THERAPY. Cain, C. A.; Tompkins, W. A.; Dunn, F. (Univ. Illinois, Urbana Champaign Campus, Sch. Engineering, Dept. Electrical Engineering, 2527 Hydrosystems Lab., Urbana, IL 61801).

The effects of hyperthermia, ultrasound, and microwave treatment of tumor cells on different parameters of the immune response will be evaluated using a syngeneic hamster tumor system. Research could lead to the development of techniques that render tumor cells more immunogenic and/or antigenic, perhaps resulting in enhancement of tumor rejection mechanisms. The proposed work will include: (1) in vitro experiments that will result in a quantitative description of changes in sensitivity of tumor cells to immune lysis following treatment and (2) in vivo tests to determine the immunologic effects of treatment of growing tumors by hyperthermia induced by ultrasound or microwave radiation. Immunologic reactivity in vitro will be correlated with observed tumor regressions in vivo. Available sensitive assays to quantitate immune responses to tumor antigens will be employed. (funding period 4/79-3/80)

Supporting Agency:HEW, PHS, NIH, NCI

0511 CHROMOSOMAL EFFECTS OF 2.45 GHz MICROWAVE NON-THERMAL EXPOSURE. Yao, K. (Genetic Studies Section, BRH, HEW, 5600 Fishers Lane, Rockville, MD 20852).

A specially designed chamber for nonthermal microwave exposure will be used to investigate microwave effects on chromosomes of cultivated cells. The chamber disperses heat quickly into a waterbath, which has a controllable temperature. Cells will

be irradiated at G_2 and M stages, the two stages most sensitive to irradiation. Temperature of the waterbath will be 25 C, 37 C, and 42 C. (funding period n/a)

Supporting Agency:HEW, PHS, FDA, BRH

0512 EFFECTS OF MICROWAVES ON NEURAL RESPONSE. McRee, D. I. (Microwave Res. Section, Natl. Environmental Health Sciences, NIH, PHS, HEW, P.O. Box 12233, Research Triangle Park, NC 27709).

The effect of microwave radiation on neurologic response will be analyzed in isolated neurons, such as the abdominal ganglion of the *Aplysia*, the sciatic nerves of frogs, and the saphenous nerves of cats exposed to continuous wave, pulsed and modulated microwave radiation in the power density range of 1-10 mW/cm^2. The effects of the microwave radiation on the strength-duration of a stimulus to produce an action potential, amplitude of the response, and conduction velocity will be investigated. The fatigue and recovery of the neurons under rapid, multiple stimulation will also be studied. A series of experiments to determine if continuous wave, 2,450 MHz microwave radiation increases the fatigue rate or changes the vitality of the frog sciatic nerve were completed. The frog sciatic nerves were exposed in a waveguide to specific absorption rates of 100 W/kg, 50 W/kg, and 20 W/kg. The nerves were stimulated with twin pulses (separated by 5-msec intervals) at a repetition rate of 500 pulses/sec to accelerate the rundown time. Distinct changes in the excitability and refraction of the exposed nerve were seen in comparison to the control nerve. The vitality of the nerves was affected and was greater for the higher dose rates. (funding period n/a)

Supporting Agnecy:HEW, PHS, NIH, Natl. Inst. Environmental Health Science

0513 EPIDEMIOLOGY OF MAGNETIC EFFECTS ON HUMANS. Budinger, T. F. (Lawrence Livermore Lab., Univ. California, P.O. Box 808, Livermore, CA 94550).

An epidemiologic study of 2,000 scientists and technicians who have been exposed to high magnetic fields for substantial cumulative exposures will be conducted, and a previously completed study of 1,500 workers who had ill effects from magnetic field exposures will be analyzed. Medical data on at least 500 exposed subjects, 500 matched controls, and 2,000 case histories of cyclotron workers and high energy researchers will be included in a data base. A potential data base for high tension linemen, power station operators, and European scientists will be investigated. (funding period n/a)

Supporting Agency:U.S. Dept. Energy, Div. Biomedical and Environmental Res.

0514 IDENTIFICATION OF PERIPHERAL AND CENTRAL RECEPTORS MEDIATING THE EFFECTS OF MICROWAVE RADIATION ON BRAIN ACTIVITY. Wilson, R. (Res. Triangle Inst., P.O. Box 12194, Research Triangle Park, NC 27709).

The effect of pulsed microwave radiation on auditory nerve activity will be studied with an electrophysiologic technique that involves recording the response of single units in auditory nerve and cochlear nucleus to microwave and acoustic stimuli. The ^{14}C-2-deoxyglutathione method will also be used in some instances to corroborate and complement the results. An additional set of experiments using the ^{14}C-2-deoxyglutathione method is proposed to detect effects of nonionizing radiation on the activity of brain structures other than nuclei of the auditory system. With this method the effects of nonionizing radiation on the activity of nuclei in sensory systems, resulting from stimulation of peripheral receptors, can be identified and separated from pervasive effects on brain activity, resulting from radiation-induced shifts in the environment of central neurons. Possible effects on brain activity resulting from stimulation of vestibular and hypothalamic receptors will also be evaluated as will possible effects resulting from radiation-induced alterations in the permeability of the blood-brain barrier and in the binding of calcium ions in cerebral tissue. (funding period n/a)

Supporting Agency:EPA, Office of Energy, Minerals, and Industry

0515 DETRIMENTAL BIOLOGICAL EFFECTS OF MAGNETIC FIELDS. Baum, J. W. (Brookhaven Natl. Lab., U.S. Dept. Energy, Upton, NY 11973).

A study of somatic, genetic, and developmental effects using mutations in *Tradescantia* stamen hairs (somatic tests) and *Drosophila* (genetic and developmental effects) is planned. *Tradescantia* cuttings will be exposed for periods from 1 to 20 days in fields of intensity from 1 to 100,000 Oe. *Drosophila* will be exposed continuously for several generations in preliminary screening studies. Later, genetic and developmental effects will be separated by exposing flies only before mating for a 12-hr period. Effects of field intensity, field gradient, and exposure time will be explored. Results will be compared to previous findings involving ionizing radiation and various chemical mutagens. Implications for exposure to man will be considered in terms of appropriate permissible exposure standards for workers and the general public. (funding period n/a)

Supporting Agency:U.S. Dept. Energy, Div. Biomedical and Environmental Res.

0516 MICROWAVE EXPOSURE SYSTEMS AND MICROWAVE DOSIMETRY. McRee, D. L. (Microwave Res.

Section, Natl. Inst. Environmental Health Sciences, NIH, PHS, HEW, P.O. Box 12233, Research Triangle Park, NC 27709).

Exposure systems for bioeffects research and test techniques for measuring energy absorption will be developed. The waveguide system for exposing isolated neurons to 2,450 MHz microwave radiation has been modified so that longer survival times and constant nerve temperatures during exposure could be achieved. Small thermistor probes have been used to measure deep colonic temperatures in pregnant mice during exposures to 2,450 MHz microwave radiation. Average absorption rates, calculated from the temperature profiles of the sacrificed mice, agreed with both calculated and measured whole-body absorption reported in the literature. A system for exposing marine animals to different intensity levels simultaneously without significant perturbation of the microwave field by the location and orientation of the animals has been developed and tested. (funding period n/a)

Supporting Agency:HEW, PHS, NIH, Natl. Inst. Environmental Health Sciences

0517 PROGRAM ON THE QUANTITATION OF THE EFFECTS OF ELECTROMAGNETIC ENERGY ON HUMAN TISSUE. Guy, A. W. (Medical Rehabilitation Res. and Training Center, 15th Ave. N.E., Seattle, WA 98105).

The electromagnetic (EM) field patterns due to external sources of energy in and around human and test animal tissues will be measured with thermographic and thermocouple techniques to elucidate the effects of EM radiation on the body and to provide realistic guidelines for safety standards of human exposure (with respect to the source, configuration, frequency, and location). Test animals will be exposed to various continuous wave and modulated EM sources at both thermal and nonthermal power levels and the physiologic characteristics and behavior of the animals before, during, and after exposure to EM radiation will be monitored. In addition, the time and power density thresholds for cataract production in animals exposed to microwave radiation will be studied. Theoretic analysis will involve solution of Maxwell's equation for absorbed power by biologic systems for a variety of geometries. In experiments conducted to date, all observed changes in the central nervous system of animals exposed to EM fields were thermal in nature. The most pronounced effects appeared to be latency changes in evoked brain potentials in cats exposed to EM fields. An experiment of chronic exposure with rats demonstrated the auditory nature of microwave behavior control, and provided cogent evidence that microwave pulses activate only the auditory sensory modality at the incident power densities employed. No significant differences were found between four irradiated and four normal animals with respect to the cataractogenic effects of microwaves. Additional experiments concerning the effect of microwaves on lymphocytes and the amounts of microwave power that might be absorbed by women and children have been conducted. (funding period 1/70-6/80)

Supporting Agency:HEW, Office Human Development Services, Rehabilitation Services Admin.

0518 MICROWAVE HYPERTHERMIA SYSTEMS FOR CANCER TREATMENT. Cheung, A. Y.; Taylor, L. S.; Scott, R.; Robinson, J. E.; Harrison, G. H. (Sch. Medicine, Baltimore Professional Sch., Div. Radiation Therapy, Univ. Maryland, 1420 N. Charles St., Baltimore, MD 21201).

The design, construction, and preclinical testing of advanced microwave applicators for hyperthermia treatment of deep-lying cancers will be studied theoretically and experimentally in a special "phantom" facility. The design will be optimized to evaluate and calibrate the deep-heating performance of the systems in in vivo animal experiments. In preliminary studies, applicators for internal introduction of microwave heating fields via electromagnetic syringes or catheters, such as stomach tubes, were shown to be feasible. External systems, employing conformal microstrip antennas or arrays of miniature waveguide applicators and bolus techniques to focus the fields, were also found to be useful for establishing microwave heating fields. (funding period 9/78-7/79)

Supporting Agency:HEW, PHS, NIH, NCI

0519 EFFECTS OF CHRONIC EXPOSURE TO EMR ON IMMUNE DEFENSE MECHANISMS OF ANIMALS. Smialowicz, R. J. (Health Effects Res. Lab., EPA, Durham, NC 27711).

The effects of long-term exposure of rats in utero and/or during early life to electromagnetic radiation at a forward power of 500 W at 100 MHz on lymphocyte function will be investigated. In addition, the effect of 915 MHz for 20 hr/day for 1-2 mo on the immune function of adult rats will also be investigated. Hematologic and immunologic indices will be measured and compared between sham- and microwave-exposed rats. Complete blood counts, enumeration of frequencies of B- and T-lymphocytes in lymph nodes, nitrogen-stimulated lymphocyte responses, and growth rates in rats will also be compared. Rats were exposed in utero and will be exposed through 90 days of age in the chronic study. Data from rats sacrificed at 22 and 42 days of age show no difference in the hematologic and immunologic indices measured between sham- and microwave-exposed rats. Exposure of rats to 915 MHz is anticipated to begin in a few months. (funding period n/a)

Supporting Agency:EPA, Office Res. and Development, Health Effects Res. Lab.

0520 MORTALITY, INDUSTRIAL HYGIENE STUDY OF WORKERS EXPOSED TO MICROWAVE AND RADIO

FREQUENCY ENERGY. Egan, E. (Survey Hazard Evaluation, Field Study Div., NIOSH, HEW, 4676 Columbia Parkway, Cincinnati, OH 45226).

NIOSH plans to conduct a retrospective mortality study to further investigate the health effects resulting from long-term, low-level exposure to electromagnetic radiation. Recent evidence indicates that the development of cancer at certain sites may be associated with exposure to electromagnetic radiation. At a naval air station at Quonset Point, Rhode Island, three civilian employees among a group of eight technicians who were engaged in the overhaul and repair of Tactical Airborne Navigation Equipment either have developed cancer or died of it since 1970. Two of the men, 31 and 35 yr of age, developed pancreatic cancer, a rare occurrence, since 99% of all reported cases of pancreatic cancer occur in persons over 40 yr of age. (funding period n/a)

Supporting Agency:HEW, PHS, Center Disease Control, NIOSH

0521 RADIO FREQUENCY/MICROWAVE TERATOGENIC EFFECTS STUDY. Conover, D. (Biomedical and Behavioral Sciences Div., Natl. Inst. Occupational Safety and Health, HEW, 4676 Columbia Parkway, Cincinnati, OH 45226).

A pilot study will be initiated to determine the types of effects produced following radio frequency (RF) irradiation of rats during gestation. Groups of animals will be irradiated at high power levels at 27.12 MHz on days 1, 3, 5, 7, 9, 11, 13, and 15 after conception. The study will include evaluation of preimplantation and resorption losses and skeletal and gross malformations. Follow-up studies will determine the threshold level for these effects. Work in progress under an interagency agreement with NBS will lead to the development of a total power absorption analyzer system. The system will be employed to noninvasively determine the distribution and magnitude of absorbed RF power to aid in extrapolating the results of the animal studies to humans. (funding period n/a)

Supporting Agency:HEW, PHS, Center Disease Control, NIOSH

0522 TERATOGENIC EFFECTS OF 915 MHz IN RATS. Berman, E. (Health Effects Res. Lab., Office Res. and Development, EPA, Research Triangle Park, NC 27711).

The teratogenicity of a daily exposure of 915 MHz microwaves in gestating rats will be investigated by examining the fetuses. Circularly polarized exposure units have been assembled. (funding period n/a)

Supporting Agency:EPA, Office Res. and Development, Health Effects Res. Lab.

0523 MICROWAVE DOSIMETRY IN BIOLOGICAL SYSTEMS. Tripathi, V. K. (Sch. Engineering, Oregon State Higher Educational System, 200 Covell Hall, Corvallis, OR 97331).

A simplified model of prolate spheroid shape and incident frequencies near resonance (incident wavelength and object size of comparable magnitude) was used to find mathematical solutions to help explain the interaction of electromagnetic energy with biologic systems. (funding period n/a)

Supporting Agency:EPA, Office Res. and Development, Health Effects Res. Lab.

0524 EFFECTS OF MICROWAVE EXPOSURE ON INFECTIOUS AGENTS IN LABORATORY ANIMALS. Liddle, C. G. (Developmental Biology Branch, Health Effects Res. Lab., EPA, Durham, NC 27711).

Animals will be infected with type III *Streptococcus pneumoniae* and exposed to various frequencies and power densities of microwaves to determine if the radiation alters the course of disease in animals exposed to an infectious agent. The results should provide information on whether microwave exposure is deleterious to sick or debilitated individuals, which may be useful in setting population exposure standards. The first group of mice was infected and exposed to 2,450 MHz microwaves at an incident power density of 10 mW/cm^2 for 5 hr/day for 6 days. Preliminary results indicate that at this frequency and power density there is no difference in acute mortality between the exposed animals and the sham-irradiated controls. (funding period n/a)

Supporting Agency:EPA, Office Res. and Development, Health Effects Res. Lab.

0525 BIOLOGICAL EFFECTS OF MAGNETIC FIELDS. Mahlum, D. D. (Battelle Pacific N.W. Lab., U.S. Dept. Energy, P.O. Box 999, Richland, WA 99352).

Pregnant mice will be exposed at varied times after conception to magnetic fields ranging up to 5,000 G, and the frequency and type of abnormalities in the offspring will be observed. Changes in litter size, behavioral activity, and growth will also be determined. The potential biologic impact of magnetic fields will be determined over the range where human exposure may occur in a proposed nuclear fusion plant. (funding period n/a)

Supporting Agency:U.S. Dept. Energy

0526 PRIMATE TRACKING PERFORMANCE DURING MODULATED 1.2 GHz EXPOSURES. Scholl, D. M. (Sch. Aerospace Medicine, U.S. Air Force, Brooks Air Force Base, San Antonio, TX 78235).

Nonhuman primates will perform a compensatory visual task under 2-hr long radio frequency (RF) exposures that meet or exceed current safety criteria to explore the possible behavioral effects of RF exposure and to respond to literature reports of low-power level RF effects. The task will require