cate their need. Individual AM and FM radio and VHF, UHF, and radar transmitters, however, should be closely monitored to determine exposure levels at populated sites in proximate areas. (13 references)

0467 EXPERIMENTAL STUDIES CONCERNING THE INFLUENCE OF THE MAGNETIC FIELD ON THE BLOOD. *(Rum.)* Savciuk, N. (I. I. Mechnikov State Univ., Odessa, USSR), T. Soldatenko, and O. Savciuk. *Igiena* 23(2):107-110, 1974.

After 5 days of exposure to a magnetic field, test animals showed a fall in hemoglobin concentration by 11.8%, increase in number of erythrocytes (15.3%), and decrease in erythrocyte sedimentation rate. Longer exposure resulted in a markedly shorter coagulation rate and, after 15 days, coagulation took place instantly, erythrocyte sedimentation rate was 3 times as short as controls, the number of lymphocytes was reduced by 12.8%, eosinophils by 8%, and neutrophil granulocytes by 10%. The influence of the low intensity magnetic field and prolonged action thus resulted in changes of the blood composition and coagulation rate and changes in cholinesterase activity of the brain. (No references)

0468 ON THE CEREBRAL AND PERIPHERAL CIRCULATION IN PERSONS DEALING WITH SOURCES OF ULTRAHIGH RADIO-FREQUENCIES, BASED ON THE RESULTS OF RHEOGRAPHIC INVESTIGATIONS. *(Rus.)* Yadrintsev, V. A. (Inst. Ind. Hyg. Occupational Health, Moscow, USSR). *Gig. Tr. Prof. Zabol.* (2):18-21, 1975.

A general clinical examination and an investigation into the cerebral and peripheral circulation using rheovasoencephalography and rheoencephalography were carried out in persons exposed to ultrahigh radio frequencies. Hemodynamic disturbances of the peripheral circulation, lability of pulse filling, and increased resilient-viscous properties of the finger vessels were found. Hemodynamic indices of the vessels in the brain, forearms and shins remained unchanged. Deviations were more pronounced in persons with vegeto-vasal disorders. Thus, rheographic characteristics of hemodynamic shifts may be used for objective evaluation of functional deviations in health status of ultrahigh radiofrequency operators. (12 references)

0469 THE EFFECT OF SUPERHIGH FREQUENCY FIELDS OF VARIOUS INTENSITIES UPON THE BALANCE AND INTERORGAN METABOLISM OF COPPER, MANGANESE, MOLYBDENUM AND NICKEL IN THE ORGANISM OF EXPERIMENTAL ANIMALS. *(Rus.)* Gabovich, R. D. (Kiev Med. Inst., USSR), A. A. Minkh, and I. A. Mikhalyuk. *Vestn. Akad. Med. Nauk SSSR* (3):16-22, 1975.

A wide spectrum of biological effects were noted in albino rats exposed to SHF fields of various intensities. Changes were noted at very low density ($10\ \mu V/cm^2$) and reliable changes indicated by homeostatic disturbances were observed under higher SHF field densities. Exposure caused shifts in balance and inter-organ distribution of trace elements such as copper, manganese, molybdenum and nickel, and changes in metabolism of the trace metals. (8 references)

0470 THE USE OF AN AUTOMATED POPULATION DATA BASE IN POPULATION EXPOSURE CALCULATIONS. *(E.)* Athey, T. W. (EPA, Off. Radiat. Programs, Silver Spring, Md.), R. A. Tell, and D. E. Janes. *Symposium on Population Exposures* (J. C. Hart, R. H. Ritchie, and B. S. Varnadore, Ed.), pp. 29-36, October, 1974.

The assessment of potential hazard to the population from a source in the environment often requires a knowledge of the specific geographic population distribution around the source. Thus, the EPA Office of Radiation Programs has adapted a computer program package and data base for use in population exposure problems in ionizing and nonionizing radiation areas. The data base consisted of the U.S. Census Bureau Master Enumeration District List with coordinates. The programs generate the total population within selected distances and angular sectors from a reference point designated by its geographic coordinates. Alternately, the programs can be used as subroutines to make available to another program the distance and bearing of each census enumeration district, in a selected region, from a reference point. The potential applications of this population distribution system to exposure problems include single-source discharge from facilities in the nuclear fuel cycle and exposure from nonionizing radiation sources such as radio, television, radar, and microwave transmitters. The population exposure from AM radio standard broadcast stations in the Baltimore-Washington area is discussed in detail. Preliminary measurements around a 50 kW station showed values of 8-12 V/m at 0.1 mile or less; it was estimated that about 3000 persons are exposed at levels of 5-10 V/m. The Russian standard for 0.1-1.5 MHz is 20 V/m^3, which probably should not be exceeded by single 50 kW stations. (3 references)

0471 BIOMEDICAL EVALUATION OF LOW FREQUENCY (LONG WAVE) ELECTROMAGNETIC RADIATION ASSOCIATED WITH ELECTRIC POWER TRANSMISSION. *(E.)* Pogrund, R. S. (Sch. Public Health, Univ. Illinois Med. Cent., Chicago). *Symposium on Population Exposures* (J. C. Hart, R. H. Ritchie, and B. S. Varnadore, Ed.), pp. 395-404, October, 1974.

Considerable scientific attention has focused on the possible hazards to human health from such sources of electric power as nuclear and fossil fuels. These hazards have been associated with the release of ionizing radiation during normal reactor operation or accident, as well as inhalation of gaseous and particulate effluents during the burning of fossil fuels. Serious attention should also be given to

the biologic effects of ELF (45-74 Hz) EM radiation associated with electric power transmission. Future generators and transmitters of electrical power may approach the dimensions of the U.S. Navy's Sanguine system, which was to have been a single transmitter complex with a capability for communicating with submarines at operating ocean depths. At the Sanguine frequency of 45 Hz, with free space wavelengths of 6600 km, the radiated ELF signal could penetrate the ocean depth without significant attenuation. A review of biomedical and psychophysiological data shows subtle ELF effects on populations at risk due to residential proximity to transmission lines, or to genetic susceptibility. The effect is both frequency dependent in the EEG range of modulation wavelengths (1-30 Hz) and resonant at small power densities (pulsed or continuous). While the primary effect is on the central nervous system, the exact mechanism of action is assumed to exist at the biochemical molecular level. Human and animal exposures to these energies produce changes in EEG and conditioned reflexes; changes in sensitivity to light, sound, and olfactory stimuli; and cerebral cortex biocurrents. VLF, UHF, VHF, and ELF EM radiation effects are summarized in a table that shows, for each observed effect, frequency, field strength or power density, and references or investigators. (22 references)

0472 TEMPERATURE DISTRIBUTION PRODUCED IN MODELS BY THREE MICROWAVE APPLICATORS AT 433.92 MEGAHERTZ. *(E.)* Lehmann, J. F. (Dep. Rehabil. Med., Univ. Washington, Seattle), A. W. Guy, J. B. Stonebridge, C. G. Warren and B. J. DeLateur. *Arch. Phys. Med. Rehabil.* 56(4):145-151, 1975.

Temperature distributions produced in phantom models by diathermy applicators operating at the nonapproved frequency of 433.92 MHz and by an experimental cooled contract applicator operating at 915 MHz were compared. The 433.92 MHz applicators were the Rundfeldstahler, a capacity loaded dipole designed for localized treatment; the Langfeldstrahler, which can be applied parallel to the back musculature and spine or parallel to limb segments such as thighs; and the Pyrodor, designed for application across the back, buttocks, chest, and abdomen. The specially designed direct contact applicator with surface cooling elevated deep muscle temperatures as effectively as the Rundfeldstrahler in spite of the better penetration of energy at the lower frequency. The Pyrador and the Langfeldstrahler, the largest of the applicators operating at 433.92 MHz, do not appear to offer any advantage over existing diathermy equipment. The highest temperatures produced with these applicators were at the fat-muscle-interface. (18 references)

0473 BIOLOGICAL INTERACTIONS BETWEEN RADIOFREQUENCY ELECTROMAGNETIC WAVES AND IONIZING RADIATION. *(E.)* Davydov, B. I. (no affil.), V. V. Antipov and V. S. Tikhonchuk. *Kosm. Issled.* 12(1): 129-133, 1974.

Mortality, life span, and changes in body wt and leukocyte count were studied in female mice exposed to an SHF field (λ = 12.6 cm) for 10 days at power flux densities (PFD) of 10, 20, 40, and 100 mV/cm^2 for 40, 20, 10, and 4 min, resp., followed by ^{60}CO irradiation at 400-900 R (25 R/min) or 1000-20,000 R (300 R/min). Preliminary exposure to the SHF field (20 mV/cm^2 and above) before γ irradiation reduced the median life span of animals; the effect was greatest at 100 mW/cm^2 and was diminished at increasing doses of γ irradiation. The reduction in median life span induced by consecutive MW and γ irradiation occurred at doses causing damage to the hematopoietic system. Synergism between nonionizing and ionizing irradiation was not found at dose levels reflecting lesions of the gastrointestinal tract. Investigation of the median lethal dose (SHF + γ) as a function of PFD suggested that at a PFD of 40 mV/cm^2, the dose of ionizing radiation should be about 100 R less. This hypothesis was confirmed by experiments in which animals were exposed to SHF + 400 R γ irradiation or to 500 R γ irradiation alone. Under both conditions, survival dynamics were virtually identical over a 22 month period. Exposure to the SHF field stimulated wt gain and caused marked fluctuations in leukocyte count. The increase in wt can be regarded as a manifestation of disfunction of the endocrine glands, especially of the hypothalamo-hypophyseal system, rather than as an adaptive reaction. The effect on leukocyte count can be attributed to the appearance of autonomic and hormonal instability. These findings demonstrate that EM waves and ionizing radiation have a synergic effect on the hematopoietic system. (17 references)

0474 PRELIMINARY REPORT: MICROWAVE FIXATION OF HUMAN TISSUES. *(E.)* Gordon, H. W. (Univ. California Irvine Sch. Med., Irvine), and E. J. Daniel. *Am. J. Med. Technol.* 40(10):441-442, 1974.

Substitution of MW radiation for routine fixation in 10% formalin effectively reduced the elapsed time between tissue selection and microscopic examination. Blocks of 1.0 x 1.5 x 0.5 cm lung, heart, liver, kidney, spleen, and skeletal muscle human autopsy tissue were exposed to MWs from a commercial MW oven in air, saline, water, 10% formalin, and Zenker's solution for 15 sec to 3 min. The experimental tissues were then processed omitting formalin but using conventional procedures otherwise. Control tissues were conventionally processed. Tissues exposed in water, saline, and 10% formalin showed an absence of shrinkage and surface distortion and an increase in stain contrast. Cytological preservation was excellent, with good preservation of nuclear membranes, adequately clumped chromatin, and well defined cellular membranes. The experimental tissues were rated equal to or superior to chemically fixed specimens. An exposure time of 30-45 sec in 300 ml fluid produced formalin equivalent fixation without altering criteria for establishing malignancy. MW radiation must take place in a fluid medium to assure artifact-free tissue. The major

advantage is a marked reduction in time required for fixation of tissues prior to dehydration and hardening. (3 references)

0475 ARTIFICIAL VISION PROGRESSES. *(E.)* Ivall, T. E. (Ed., *Wireless World*). *Wireless World* 81(1472):156-158, 1975.

Design improvements in the Medical Research Council's microwave implant for the blind are reported. The principle of this visual prosthesis is to stimulate directly a large number of points on the visual cortex of the brain of a person who has become blind, for example, through damage to the optic nerve. The patient 'sees' spots of lights (phosphenes) which are fixed in the visual field and which can be arranged into meaningful patterns by suitably organizing the electric stimulation. The stimulation is applied by 500 μsec pulses of current fed to electrodes mounted in silicone rubber cups in the two occipital lobes of the brain. To provide more stimulation points and to reduce the size of the implant, the hermetic sealing of logic units containing transistor and diode AND gates was replaced by encapsulation with silicone rubber adhesive. With this encapsulation logic packages containing nineteen AND gates (as against the previous twenty) have been produced measuring only 26 mm x 7 mm x 3 mm. The smaller size of the package allows more logic units to be used (sixteen instead of nine); these will be fed with d.c. pulses from 16 row receivers and 19 column receivers, giving 16 x 19 unique pairs of receivers on the matrix and therefore allowing 304 stimulating electrodes. The number of stimulation points will be quadrupled in the new implant. Other improvements include thick-film logic circuits and the use of tantalum electrodes coated with tantalum pentoxide. With this coating, the capacitor and stimulating electrode are combined into one. (5 references)

0476 MICROWAVES IN RADIOTHERAPY OF TUMORS - ALTERNATIVE TO HEAVY PARTICLES? *(E.)* Dietzel, F. (Cent. Radiol., Justus Liebig Univ., Giessen, Germany), D. Ringleb, U. Schneider, and H. Wricke. *Strahlentherapie* 149(4):438-441, 1975.

MWs used in combination with sparsely ionizing radiation cause an increase in radiosensitivity in treatment of tumors. The therapeutic effect was tested on an euoxic tumor (mice testicles) and a tumor containing parts of hypoxic cells (solid tumor of Erlich). 490 NMRI male mice testicles were irradiated with 120 rd and 340 solid Ehrlich neck tumors (1 ml tumor vol) were irradiated with 2000 R. Both were immediately followed by heating with MWs (461.04 MHz) to 40-43 C. The combined treatment was evaluated 20 days after therapy. Neither group was affected by heating to 40-41 C; however, heating to 42-43 C led to significant weight reduction of both testicles and tumor. In combination with x-ray treatment, increased sensitivity developed in the tumor at 40-41 C, but not in the testicles. The temperature enhancement ratio is not a linear function of the temperature. Suitable combinations of UHF and sparsely ionizing radiation could replace therapeutic methods with heavy particles in the future. (13 references)

0477 MITOTIC DELAY IN THE SLIME MOULD *Physarum polycephalum* INDUCED BY LOW INTENSITY 60 AND 75 Hz ELECTROMAGNETIC FIELDS. *(E.)* Marron, M. T. (Div. Sci., Univ. Wisconsin-Parkside, Kenosha), E. M. Goodman, and B. Greenebaum. *Nature* 254(5495): 66-67, 1975.

The effects of low frequency EMFs on the mitotic cycle of the myxomycete *Physarum polycephalum* were examined. Crossed electric and magnetic fields alternating in phase at 60 or 75 Hz at levels of 0.7 V/m and 2.0 gauss, corresponding to fields generated by the U. S. Navy's proposed Project Sanguine communications antenna, were used. A significant mitotic delay became evident after 80-100 days in a 75 Hz EMF. After removal from the field the delay persisted from 30-60 days during which time the mitotic interval converged with that of the control. No significant delay was observed in cultures exposed to weaker 75 Hz EMFs (0.15 V/m, 0.4 gauss) for 200 days. Thus, low level EMFs can influence biological systems; the delay in mitotic cycle shows up only after long exposure periods and does not disappear immediately after removal from the EMF. (9 references)

0478 ELECTROMAGNETIC FIELDS AND SKIN WOUND REPAIR. *(E.)* Romero-Sierra, C. (Dep. Anat., Queen's Univ., Kingston, Canada), S. Halter, J. A. Tanner, M. W. Roomi, and D. Crabtree. *J. Microwave Power*, 10(1):59-70, 1975.

Experiments were set up to see whether EM nonionizing energy, which stimulates and enhances collagen production in tissue, has a beneficial effect in wound repair. Two sets of experiments were performed. In the first, 2 groups of Sprague-Dawley rats were given 1.5 cm incisions in their backs. The wounds were pretreated with 2 drops of either saline or histamine diphosphate (1.0 mg/ml). Half of each group was exposed to a VHF (27 MHz) field for 15 min while edges of the wound were apposed by manual pressure. Tissues were examined microscopically after 12, 24, and 72 hrs. Marked differences were noted after 12 hrs: In control groups, distance between edges of the wound was much greater than in the test group and the only sign of organization was infiltration of acute inflammatory cells. In the irradiated test groups the wound area was difficult to identify. Wounds treated with the EM field had less of a polymorphonuclear infiltrate and more fibroblasts and macrophages in the incisions suggesting these were healing 24 hr ahead of the unexposed controls. The most efficient wound treatment was histamine plus irradiation, with saline plus irradiation, histamine, and saline successively less effective. The greatest effort occurs within 12 hrs of treatment. In the second experiment, ten

9-11-mon-old beagle dogs were given a single 2.5 cm incision in the right foreleg. In 5 days skin was removed from the wound area and tested for tensile strength. The average value for test dogs was 530 g *vs* 141 g for controls and the cosmetic appearance of the wounds were consistently superior in test dogs. Thus, wounds treated with radiation heal more quickly, are stronger, are superior cosmetically and leave a smaller scar. (5 references)

0479 EXPOSURE OF RABBIT ERYTHROCYTES TO MICROWAVE RADIATION. *(E.)* Hamrick, P. E. (Natl. Inst. Environ. Health Sci., Research Triangle Park, N.C.) and J. G. Zinkl. *Radiat. Res.* 62(1):164-168, 1975.

Rabbit erythrocytes were exposed to MW radiation at 2450 and 3000 MHz (CW) in an attempt to duplicate reported changes in the erythrocyte membrane permeability to potassium and changes in osmotic resistance. At 2450 MHz, 1-4 hr exposures were made at intensities of 4, 10, and 75 mW/cm^2 with absorbed power densities of 3, 7.6, and 57 mW/g, resp. At 3000 MHz, the erythrocytes were exposed for 1 or 3 hr to 5 mW/cm^2 (5.2 mW/g absorbed power). The suspending medium was buffered saline with or without glucose at 2450 MHz and unbuffered saline at 3000 MHz. Results of all experiments showed no significant difference between exposed and control erythrocyte suspensions in either potassium efflux or in osmotic resistance. (4 references)

SOURCE: Proceedings of the conference entitled Biologic Effects of Nonionizing Radiation sponsored by The New York Academy of Sciences, February 12-15, 1974.

0480 OVERVIEW OF ELECTROMAGNETIC RADIATION RESEARCH: PAST, PRESENT, AND FUTURE. *(E.)* Tyler, P. E. (EMR Proj. Off., Dep. Navy., Washington, D.C.). *Ann. N. Y. Acad. Sci.* 247, 6-14, 1975.

The historical irregularity of interest and active research in biological effects of EM radiation since its discovery in 1888 are reviewed. The contemporary technological advances and the use of EMR in medicine, industry, research, communications, military systems, and the home; concern with the environment; and recent legislation on health and safety have stimulated the rebirth of biological research in EM radiation. The role of OTP in reviewing, advising, and making recommendations on the potential problems associated with the use of the EM spectrum are discussed. Although most current research is federally funded, it may be unfortunate that there is no single source of major funding since there are many other projects of higher priority within each agency. The nonthermal/thermal discussions should be dropped and instead interest should be focused on the energy absorbed and the presence of a specific field intensity. New approaches are needed. The accumulating evidence that the magnetic component may be of greater significance than previously thought should be studied; as frequency decreases, in the low MHz to kHz range, the magnetic portion may become the major portion. Modulation is another area only recently believed to be important, and knowledge of the possible additive or synergistic effects of multiple frequencies or other agents requires added attention. Genetic effects of EM radiation are also a critical, unanswered question, and their effects on growth and development of organisms is of related importance. Effects upon the CNS, cataractogenesis, and the problem of dosimetry, densitometry, and measurement are other areas for concerted research. As the Richmond Symposium, held in Richmond, Va., in 1969 pointed the way for subsequent research, the N. Y. Academy of Sciences Conference on the Biologic Effects of Nonionizing Radiation will spotlight the research needed in ensuing years. (25 references)

Part I. Effects on the Nervous System

0481 INTRODUCTION: EFFECTS OF ELECTROMAGNETIC RADIATION ON THE NERVOUS SYSTEM. *(E.)* Adey, W. R. (Brain Res. Inst., Univ. California, Los Angeles). *Ann. N. Y. Acad. Sci.* 247, 15-20, 1975.

It is suggested that EMR may be an important tool to be used in unraveling the problems of structural and functional organization of the brain. Far beyond the phenomenological effects currently studied, proper research with NIR may give information about transmission, transaction, storage, and retrieval in brain tissue. Interactions with the mammalian CNS can be produced by oscillating electric and EM fields with temperature changes of < 0.1 C, far below natural pertubations in brain temperature. Responsiveness to weak EM fields is due to the collective properties of the cellular elements which may not be discernable in the separate behavior of individual elements. The brain as a whole may react to stimulation much smaller than that which occurs in postsynaptic excitation and may be represented as a hierarchic model. Molecular events at a membrane surface may influence the excitability of a particular neuron which in turn influences other neurons through a conduction process, producing a volume-conducted slow-wave field. A new awareness of the stepwise processes which initiate excitation will lead to further research on transactions of the brain. (31 references)

0482 BIOCHEMICAL AND NEUROENDOCRINE ASPECTS OF EXPOSURE TO MICROWAVES. *(E.)* Michaelson, S. M. (Dep. Radiat. Biol. Biophys., Sch. Med. Dent., Univ. Rochester, N. Y.), W. M. Houk, N. J. A. Lebda, S-T. Lu, and R. L. Magin. *Ann. N.Y. Acad. Sci.* 247, 21-45, 1975.

The neuroendocrine system forms a sensitive mode to analyze responses of the endocrine system and higher CNS centers under the influence of environmental changes and readjustments of the organism. Alterations in the secretory levels of the pituitary gland, adrenal cortex, thyroid gland, and gonads will occur in response to MW exposure at some time/intensity relationship. A review and analysis of the literature on hypothalamic, hypophysial, thyroid and

adrenal effects is presented in this paper. In addition, in an effort to synthesize previously reported effects of MW exposure, preliminary experiments are reported. Rats and dogs were irradiated with whole body and local CW MWs at 2450 MHz to resolve certain thresholds for MW-neuroendocrine interaction and to study target organ and metabolic responses to short term medium and high intensity radiation. Four hundred Long-Evans rats were exposed to 150 min irradiation after adaptation for 2 wks. They were then weighed, decapitated, exsanguinated and colonic temperature was taken. All levels of exposure (9, 18, and 36 mW/cm^2) indicated a distinct temperature rise; preexposure temperature levels were reached 60 min after termination of radiation. Serum GH dropped within 60 min of irradiation with 36 mW/cm^2, associated with a peak in the rise of mean whole body temperature to 40.9 C. This is compatible with a general stress reaction. Serum glucose, triglyceride, and cholesterol levels were not grossly affected. In the mammal, a principal mechanism for regulating thermal inputs is adjustment of the cardiovascular system; studies are being performed to relate neuroendocrine function and cardiovascular response to MW exposure. In studying endocrine function, all interdependent components of the system are exposed to variable degrees simultaneously; it is hard to relate effects to a particular sensitivity of any component or group of components within the system. The nature of MW interactions is not known but there are indications that irradiation can act as a 'stressor,' altering homeokinesis. There is a pattern of neuroendocrine involvement in the many physiologic adjustments of the organism relative to increased body temperature or alterations in thermal gradients within the body. (79 references)

0483 EFFECTS OF LOW-INTENSITY MICROWAVES ON ISOLATED NEURONS. *(E.)* Wachtel, H. (Dep. Biomed. Eng. Electr. Eng., Duke Univ., Durham, N. C.), R. Seaman, and W. Joines. *Ann. N. Y. Acad. Sci.* 247, 46-62, 1975.

Ganglia from the marine gastropod *Aplysia*, which are smaller than the shortest length MW employed, were studied to determine the effects of MWs on isolated nerve cells. A ganglion was placed within a MW stripline and intracellular glass microelectrodes were used to record the electric activity of individual neurons before, during, and after irradiation. Because of small sample size and simple geometry of the stripline the absorbed power could be calculated from the total incident power. The most striking effects found were changes in firing patterns of pacemaker neurons, both beating pacemakers with regular interspike intervals (ISI) and bursting pacemakers with regular interburst intervals (IBI). In *Aplysia* the ISI fires very regularly (< 10% variation) so an induced change is easily distinguished and is probably of "informational" significance to the neuron. ISI and IBI alterations were induced by MW intensities of 5 mW/cm^3 or less. When CW and PW (1-5 kHz, 10 μsec pulse width) radiation of the same average power were compared, no significant differences were detected although preliminary results indicated that pulses of 10-100 msec may have increased efficacy in synchronizing firing patterns. No differences were noted in changing from 1.5 to 2.45 GHz frequency. When irradiation was compared to heating the samples, the effect on ISI and IBI seemed to be much greater for convective heating. No significant differences in action potential size, duration or shape, or in resting potentials or conductance were noted on irradiation. It is suggested that MWs may act to change the depolarization rate of the neural membrane toward the firing level as the current density produced is 10^3 times as great as the polarizing current density needed to produce an effect on firing patterns. While the effects noted may not be harmful they would be disruptive of ongoing information handling processes if they occurred in an intact nervous system. (11 references)

0484 SOME EFFECTS OF ELECTROMAGNETIC RADIATION ON THE BRAIN AND SPINAL CORD OF CATS. *(E.)* Taylor, E. M. (Dep. Rehabil. Med., Sch. Med., Univ. Washington, Seattle) and B. T. Ashleman. *Ann. N. Y. Acad. Sci.* 247, 63-73, 1975.

Spinal cords from 49 cats (3.0 kg) were used to study effects of EMR and to evaluate effects by parallel heating and cooling. The spinal cord was chosen because of its high resolution, identifiability of active components, small aggregates of active elements, and accessibility to experimental procedures. The cats were anesthetized, an extensive laminectomy was performed, the cord was exposed, and a nerve root pair was chosen. The ventral root of this pair was elevated and sectioned. Spinal cord activity, detected at the ventral root, was recorded electronically. EM radiation (CW) at 2450 MHz, generated by a Burdick Microtherm diathermy device, was used at an absorbed power ≈ 1.6 W/cm^3. Experiments were run with bath temperature maintained at 37.5 C, in a bath cooled below 37.5 C, and without maintaining a constant temperature bath. In all cases, attenuation of the ventral root potential depended directly on temperature; as temperature increased, ventral root potential decreased, but always recovered to initial values as temperature stabilized to 37 C. Thus CNS function is altered by MW radiation, but only to the same extent as nonradiation heating. (10 references)

0485 EFFECTS OF MODULATED VHF FIELDS ON THE CENTRAL NERVOUS SYSTEM. *(E.)* Bawin, S. M. (Space Biol. Lab., Univ. California, Los Angeles), L. K. Kaczmarek, and W. R. Adey. *Ann. N. Y. Acad. Sci.* 247, 74-81, 1975.

The chick forebrain was chosen for an investigation of possible interactions between extracellular weak voltage gradients induced by the VHF radiation and ionic movement in cerebral tissue. The forebrain was used because it was previously shown to be highly sensitive to small pertubations of extracellular concentrations of Ca^{2+} and Mg^{2+}. Ca^{2+} fluxes from irradiated brains were compared at various frequencies of amplitude modulation. Experiments were conducted in a specially adapted environmental chamber at field

intensities of 1-2 mW/cm^2. Five hundred neonatal chicks were decapitated; forebrains were dissected from the cranial cavities and incubated for 30 min in 1 ml physiologic medium and 0.2 ml saline containing 0.2 µCi of $^{45}Ca^{2+}$. The samples were exposed to irradiation with sinusoidal modulation at 0.5, 3, 6, 9, 11, 16, 20, 25, or 35 Hz. In each experiment 3 series of 10 samples were irradiated with VHF fields modulated at 3 different frequencies and radioactivity was measured. An additional series of 40 chicks was used to compare field effects on $^{45}Ca^{2+}$ efflux from brains poisoned after incubation with 10^{-4} M NaCN. Preliminary experiments were also run on skeletal muscle tissue. Unmodulated radiation and fields modulated at 0.5 and 3 Hz induced no significant change in the $^{45}Ca^{2+}$ efflux, but there was a progressive increase in the efflux from brains exposed at 6, 9, 11, and 16 Hz. These effects declined at higher frequencies and results at 35 Hz did not differ from controls. This indicated that the electrochemical equilibrium existing in cerebral tissues can be disrupted by small variations of surrounding ionic concentrations or local electric gradients. A small displacement of these ions could play an important role in propagation and amplification of local electrical events. The $^{45}Ca^{2+}$ fluxes were not influenced by CN^- poisoning, suggesting that the ionic exchanges observed were independent of ongoing metabolic processes. Preliminary test results on skeletal muscle showed that no significant changes in $^{45}Ca^{2+}$ efflux were triggered from striated muscle. The calcium ion movements under observation were critically related to specific components of the radiation. (30 references)

0486 SYNCHRONIZATION OF CORTICAL NEURONS BY A PULSED MICROWAVE FIELD AS EVIDENCED BY SPECTRAL ANALYSIS OF ELECTROCORTICOGRAMS FROM THE WHITE RAT. *(E.)* Servantie, B. (Mil. Hosp. Postgrad. Stud., Sainte Anne, Toulon-Naval, France), A. M. Servantie, and J. Etienne. *Ann. N. Y. Acad. Sci.*, 247, 82-86, 1975.

An attempt was made to demonstrate the action of MW fields on cerebral neurons. Albino Charles River rats (8 test, 10 controls) were irradiated for 10 days in free space conditions in an anechoic chamber. The rats were exposed to an average power density of 5 mW/cm^2 in a 3 GHz pulsed field (1 µsec, 500-600 pps). After exposure occipital electrocorticograms were recorded and analyzed. For irradiated animals analysis yielded a line of the same frequency as that of the pusle repetition frequency of the radiation. The line is weak, but persists for several hr after termination of radiation. It is probably due to synchronization of cortical neurons by EM impulses. Two hypotheses are presented: (1) tissues of the animal head or cortex in which the electrical parameters are not linear change the impulses into electrical shocks which directly excite the neurons, or (2) the excitatory factor may be the magnetic component of the hyperfrequency field. (7 references)

0487 DO MICROWAVES ALTER NERVOUS SYSTEM STRUCTURE? *(E.)* Albert, E. N. (Dep. Anat., George Washington Univ., Washington, D. C.) and M. DeSantis. *Ann. N.Y. Acad. Sci.* 247, 87-108, 1975.

Sixty adult Chinese hamsters were used to examine the CNS after irradiation with 2450 MHz EMR in an anechoic chamber. Exposure time was 30 min to 24 hr at 50 mW/cm^2 and 22 days at 25 mW/cm^2. Animals were sacrificed immediately after exposure or after a 1-2 wk recovery period. They were processed for light and electron microscopy, and tissues were stained for various tests. Animals exposed at 50 mW/cm^2 exhibited morphologic changes in the cytoplasm of certain neuron cell bodies. The cytoplasm of hypothalamic neurons was pale and displayed vacuolization and chromatolysis; no vacuoles were present in the cytoplasm or nuclei of glial cells. Cytopathologic phenomena were more numerous in animals sacrificed immediately after exposure as compared to those sacrificed 6-10 days after treatment. At 25 mW/cm^2 there was evidence of vacuolization and chromatolysis in hypothalamic neurons and vacuolization and frothy cytoplasm of neurons in the subthalamus. However, neurons adjacent to the thalamus and other CNS regions were unaltered relative to controls at both power densities. MWs had no effect on myelin; there was no evidence of gliosis, hemorrhage, or perivascular edema. These findings suggest that MWs at 25 and 50 mW/cm^2 and 2450 MHz consistently affect the hypothalamus and subthalamus. Changes appear to be chiefly cytoplasmic, although a decrease in the protein synthesis apparatus was also found. (14 references)

0488 EXPERIMENTAL MORPHOLOGIC AND ELECTROENCEPHALOGRAPHIC STUDIES OF MICROWAVE EFFECTS ON THE NERVOUS SYSTEM. *(E.)* Baranski, S. (Mil. Inst. Aviat. Med., Warsaw, Poland) and Z. Edelwejn. *Ann. N. Y. Acad. Sci.* 247, 109-116, 1975.

Chemical and experimental studies are reviewed in this paper. Personnel who had contact with MW sources were divided into 3 groups depending on the power densities to which they were exposed, and each group was subdivided according to the duration of exposure. Neurologic investigations were performed, including a detailed history, physical examination, and EEG. Subjective complaints of headache and sweating were frequent. Personnel exposed over long periods at high power density levels generally exhibited flat EEGs. Although no firm conclusions could be drawn, observations indicated that MW exposure may influence nervous system function. In experimental tests, rabbits received single or repeated exposure to 2950 MHz CW or PW (1200 Hz, 1 µsec) MWs. Single irradiations were performed at 5-30 mW/cm^2; repeated exposure was at 5 mW/cm^2, 2 hr/day for 3-4 mon. After irradiation, EEG recordings were made and histologic, histochemical and biochemical investigations were performed. Active acetylcholinesterase centers were determined and phosphorus and protein metabolism were followed with radioactive tracers. Long term exposure to pulsed MWs yielded: (1) a fall in incorporation of ^{32}P, especially in lipid and nucleic acid fractions of brain homogenate; and (2) desynchronized high-voltage records, resulting from chronic stimulation of brain stem structures. Long term CW and PW irradiation resulted in a loss of active acetylchol-

inesterase centers and a decrease in radioactivity of different brain regions, particularly the midbrain. Pulsed MW effects were more pronounced than CW irradiation at the same mean power density and frequency. Investigations on effects of low level long term doses (5-7 mW/cm^2) have shown that MWs primarily affect reticular formation of the brain. (16 references)

Part II. Effects on Special Senses

0489 POSSIBLE PHYSICAL SUBSTRATES FOR THE INTERACTION OF ELECTROMAGNETIC FIELDS WITH BIOLOGIC MEMBRANES. *(E.)* Grodsky, I. T. (Dep. Phys., Cleveland State Univ., Ohio). *Ann. N. Y. Acad. Sci.* 247, 117-124, 1975.

A physical, quantum-mechanical, theoretical model of several aspects of the structure of the greater membrane is summarized and its correlations with current experimental results and predictions of interactions of external EMF with the nervous system are considered. The model comprises the neuronal phospholipid sheet of the plasma membrane and constituents of intracellular spaces in brain tissue. The external EMFs considered consist of gradients far below those needed for direct intervention with action potentials or chemical transmitters at synaptic sites. Problems associated with rectification of modulated signals and transduction into brain tissue are also considered. The model is viable; its predictions and correlations suggest many experiments which need to be performed beyond measuring basic interaction energies. The model may be enhanced by being complicated in many different directions when more detailed experimental information on the structure of a greater membrane has been obtained. (14 references)

0490 INVESTIGATION OF SINGLE-EXPOSURE MICROWAVE OCULAR EFFECTS AT 3000 MHz. *(E.)* Appleton, B. (Walter Reed Army Med. Cent., Washington, D.C.), S. E. Hirsch, and P. V. K. Brown. *Ann. N.Y. Acad. Sci.* 247, 125-134, 1975.

To determine the ocular effects of a single exposure to MW radiation, the eyes of anesthetized albino rabbits were exposed to 10cm (3000 MHz) CW radiation with a focusing dish antenna. Power levels and durations were well above the cutaneous sensation level. Animals which received 100 or 200 mW/cm^2 for 15 or 30 min underwent no ocular changes during or immediately after exposure, nor did a 1 yr follow-up reveal lenticular changes. Animals subjected to 15 min exposures at 300, 400, or 500 mW/cm^2 exhibited acute ocular changes during exposure. These consisted of hyperemia of lids and conjunctiva, miosis, anterior chamber flare, engorgement of iris vessels, and periorbial cutaneous burns. The miosis and flare were present for approximately 24 hr. Most of the severe changes were noted with the higher power density exposures; subsequent examinations revealed no morphologic lenticular abnormalities. Animals which received 300 mW/cm^2 for 30 min died during exposure. In addition, 3 of 6 animals exposed at 500 mW/cm^2 for 15 min died, and the 3 survivors were greatly stressed. These results correlate well with previous work at 2450 MHz, in which a single MW exposure of > 15 min was required for cataract production at 300 mW/cm^2 and above. Single exposures at 200 mW/cm^2 for 30 min were not sufficient to cause cataracts. (29 references)

0491 SCREENING FOR CATARACTS AMONG VETERAN RADAR REPAIR AND MAINTENANCE TECHNICIANS. *(E.)* McAfee, R. D. (VA Hosp., New Orleans, La.), L. L. Cazenavette, and M. G. Holland. *Ann. N.Y. Acad. Sci.* 247, 135-141, 1975.

A pilot study was initiated on a discrete population of veterans, such as radar repairmen, to see if lens changes may have occurred after discharge from the Armed Services. A simple cataract viewer was used that permitted an intelligent operator to examine his own eyes after proper instructions. The shadowgraph viewer was a low-voltage transformer in a small electrically insulated box. It contained a focused lamp which illuminated a shiny aluminum ball housed in a cylindrical viewer containing a peephole. Slit-lamp biomicroscopic examination confirmed the accuracy of drawings of entopic phenomena done by the veterans. The research group will expand the study to include individuals who had specific tasks involving combined MW and possibly ionizing radiation, those who repaired high powered communications equipment that does not produce MW radiation but may produce ionizing radiation, those who were exposed to MW radiation in the absence of possible ionizing radiation, and controls exposed to neither radiation. The survey should help clarify whether alleged latent human MW cataract exists. (7 references)

0492 USE OF A DIELECTRIC LENS FOR EXPERIMENTAL MICROWAVE IRRADIATION OF THE EYE. *(E.)* Carpenter, R. L. (HEW, Bur. Radiol. Health, Winchester, Mass.), G. J. Hagan and E. S. Ferri. *Ann. N.Y. Acad. Sci.* 247, 142-154, 1975.

Whole-body exposure of experimental animals to far-zone field MW radiation results in resonant heating which may cause death from hyperthermia. An attempt was made to resolve this problem by placing a dielectric lens in the far zone and concentrating radiation on the eye positioned a short distance behind it. Comparison of the MW power concentrated by a constant-K lens and a solid polyethylene lens showed that the former was superior in that radiation (2.45 and 10 GHz) was increased 7- to 13-fold in the eye relative to the rest of the body. During 30 min exposures of New Zealand White rabbits at 2.45 and 10 GHz, body temperature increased 6.7 and 4.3 C, resp., without the constant-K lens, compared with 1.2 and 0.5 C with the lens. Intraocular temperature at these frequencies rose 9 and 14.8 C without the lens *versus* 5.2 and 7.1 C when the lens was used. The greater rise in body temperature at 2.45 GHz suggests that radiation penetrates more deeply at this frequency and that energy is therefore absorbed by a greater volume of tissue. The

higher intraocular temperature induced by 10 GHz may reflect weaker penetration and absorption by the more superficial layers of tissue, including the highly vascular ciliary body and iris of the eye. Results for the 2.45 GHz frequency showed that with the constant-K lens, the animal had little effect on the MW power except when measurements were made 5-6 cm behind the lens. (15 references)

0493 THE OCULAR EFFECTS OF MICROWAVES ON HYPOTHERMIC RABBITS: A STUDY OF MICROWAVE CATARACTOGENIC MECHANISMS. *(E.)* Kramar, P. O. (Dep. Opthalmol., Univ. Washington Sch. Med., Seattle), A. F. Emery, A. W. Guy, and J. C. Lin. *Ann. N.Y. Acad. Sci.* 247, 155-165, 1975.

Cataract production following near-zone 2.45 GHz radiation was studied in 8-month-old New Zealand albino rabbits in which the retrolental temperature was kept below 41 C by means of general hypothermia. Initially, rectal and retrolental temperatures were measured during 30, 20, and 15 min exposures of hypothermic rabbits to absorbed power densities of 184, 276, and 368 W/kg, resp., and incident power densities of 200, 300, and 400 mW/cm^2. Results showed the necessity of establishing a general body temperature to prevent elevations above 41 C. This temperature (25-31 C) was distinct for each power level and decreased with an increase in incident power density. Under conditions of controlled hypothermia, animals exposed to 2.45 GHz at 5 cm from the corneal surface did not develop cataracts. Although slight tearing and pupillary constriction were observed immediately after irradiation, these effects disappeared on day 2. The lenses of all animals remained clear throughout a 2-3 month observation period. Measured intraocular temperature distributions in irradiated, hypothermic rabbits (rectal temperature 29.6 C, ambient air, 24.3 C, ice bath, 22.9 C) showed good agreement with values predicted by a computer model. The isothermic pattern was similar to that for normothermic animals, except for the reduced temperature levels. This study indicates that radiation-induced temperature elevations are essential for the cataractogenic effects of MWs. (8 references)

0494 ULTRASTRUCTURAL CHANGES IN THE RABBIT LENS INDUCED BY MICROWAVE RADIATION. *(E.)* Williams, R. J. (Duke Univ. Eye Cent., Durham, N.C.), A. McKee and E. D. Finch. *Ann. N.Y. Acad. Sci.* 247, 166-174, 1975.

The effects of 2450 MHz CW MW energy on the ocular lens were studied in male New Zealand white rabbits divided into two groups of 6 animals each. The first group was irradiated with 250 mW/cm^2 for 20 min/day, 5 days/wk, for a total of 6 wk; the second group was exposed to 165 mW/cm^2 for 20 min twice daily (2 hr interval), 5 days/wk, for a total of 36 exposures. When sacrificed 2 wk after the last exposure, all animals in the first group had lens opacities detectable by slit-lamp examination. In severely damaged lenses, initial biomicroscopic changes appeared during the third wk and consisted of vacuolization and haziness of the posterior subcapsular cortex; by the sixth wk, most of the posterior subcapsular cortex was opaque. At time of sacrifice, the opacity had discrete margins and resembled a disk of matted cotton centered at the posterior pole just under the capsule. Under the electron microscope, cells of the immediate subcapsular region of the lens were markedly deformed; cells between this region and the interior of the lens were variably affected. Reduplication and degeneration of the membrane was observed in some cells along with large cystoid spaces (intra- and extracellular) subjacent to the capsule at the posterior pole. Although lenses of all animals in the second group appeared normal by slit-lamp examination, electron microscopy showed substantial morphological alterations. Fibers of the posterior subcapsular cortex were generally enlarged, some containing large craters, and large intracellular clefts were present throughout the posterior subcapsular region. (5 references)

0495 ASCORBIC ACID CHANGES IN CULTURED RABBIT LENSES AFTER MICROWAVE IRRADIATION. *(E.)* Weiter, J. J. (Environ. Biosci. Dep., Naval Med. Res. Inst., Bethesda, Md.), E. D. Finch, W. Schultz, and V. Frattali. *Ann. N.Y. Acad. Sci.* 247, 175-181, 1975.

A study was conducted to evaluate nonthermal effects and radiation modulation of MWs on whole lens tissue cultures using changes in ascorbic acid concentration as an indicator of lens damage. The decrease in ascorbic acid concentration is the earliest detectable biochemical indicator of lens damage. The lenses of New Zealand white rabbits were removed aseptically, transferred to a culture medium (rabbit serum, Earle's modified salt base, penicillin, and streptomycin), and incubated at 37 C for 48 hr prior to irradiation. Effects of pulsed *vs* CW S-band radiation were compared, as well as exposure of control lens in matched time-temperature environments without irradiation to that produced by exposure to MWs. All effects produced a decrease in ascorbic acid concentration in the lenses. There was direct correlation between decreased concentration and MW power with no apparent threshold of activity. No differences were found between irradiated and control lenses subjected to identical time-temperature conditions. At any given average power density, time-temperature variation was independent of modulation; equivalent decreases in ascorbic acid concentrations were produced, indicating a purely thermal phenomenon. If the effect had been nonthermal, peak power should have been a significant factor. Therefore, MW lens damage is a thermal phenomenon; however, no critical threshold temperature was found. If repetitive insults occur before sufficient time has elapsed for repair, long-term exposure to lower power MWs might lead to irreversible morphologic damage. (15 references)

0496 DETECTION OF WEAK ELECTROMAGNETIC RADIATION BY THE MAMMALIAN VESTIBULOCOCHLEAR APPARATUS. *(E.)* Lebovitz, R. M. (Univ. Texas Southwestern Med. Sch., Dallas). *Ann. N.Y. Acad. Sci.* 247, 182-193, 1975.

Slow caloric or thermal stimulation of the vestibular apparatus is examined as a mechanism for the auditory perception of MW radiation at levels below those associated with acute thermal damage (10-30 mW/cm^2 or less in humans). The vestibular hypothesis implies that the auditory effect of MW radiation should be strongly dependent on orientation of the head relative to the vertical axis but only weakly dependent on orientation relative to the source under nonresonance conditions. Caloric vestibular effects of MWs could give rise to sensations of angular acceleration mediated *via* the semicircular canals and perhaps to ill-defined vibratory or auditory sensations mediated *via* saccule and utricle by similar thermal mechanisms. The hypothesis assumes several potential mechanisms for a behavioral cue value in MW radiation at low levels of incident power density, cues that can be derived only from basic thermal mechanisms plus the well-documented sensitivity of inner ear structures. If sharp resonance absorption can be demonstrated, MW vestibular interaction offers the possibility of developing new clinical diagnostic tools (e.g, MW based tests of vestibular function). Other mechanisms are reviewed whereby auditory and mixed audiovestibular effects might derive from weak, but modulation-sensitive, electromechanical effects of incident MW radiation, i.e., radiation pressure and dielectrophoresis. It is hypothesized that phasic displacement of the tympanic membrane should occur coincidentally with pulse-modulated MW radiation. (21 references)

0497 MICROWAVE-INDUCED ACOUSTIC EFFECTS IN MAMMALIAN AUDITORY SYSTEMS AND PHYSICAL MATERIALS. *(E.)* Guy, A. W. (Univ. Washington Sch. Med., Seattle), C. K. Chou, J. C. Lin, and D. Christensen. *Ann. N.Y. Acad. Sci.* 247, 194-218, 1975.

The threshold of the acoustic effect of pulsed MWs in man and animals was studied as a function of pulse power or energy, pulse shape, and carrier frequency. In addition, the locus of action of the effect was investigated. The studies involved establishment of incident field and modulation characteristics at the threshold for auditory sensation in humans; comparison of activity evoked in four successive levels of the auditory nervous system in the cat due to incident acoustic and MW pulses; assessment of the deactivation of the cochlea, the first known stage of transduction for acoustic stimuli on the potentials evoked by both forms of pulsed energy; quantitation of the transduction of MW pulse energy to acoustic energy in MW-absorbing materials by optical interferometry; and demonstration that the MW auditory phenomenon is consistent with direct conversion of EM energy in tissues. Two human subjects were exposed to 2450 MHz (3 pulses/sec, pulse width 1-32 μsec, background noise 45 dB). Cats were exposed to 2450 MHz (1 pulse/sec, background noise 64 dB) and 918 MHz (1 pulse/sec, background noise 64 dB). In both humans and cats, the threshold for MW pulse-evoked auditory sensations was related to the incident energy/pulse. With pulses less than 30 μsec wide, values were approximately 20 $\mu J/cm^2$ for cats and 40 $\mu J/cm^2$ for humans. These values correspond to a peak power absorbed density of 10-16 mJ/kg in the cat head and 16 mJ/kg in the human head. As background noise increased, the threshold for evoked responses in the medial geniculate nucleus of the cat remained stable for pulsed MW stimuli but increased for acoustic stimuli. Cochlear destruction resulted in total loss of all evoked potentials due to MW and acoustic stimuli, indicating that the MW auditory effect is exerted in the same manner as conventional acoustic effects. The most likely mechanism of EM field interaction is apparently conversion of EM energy to acoustic energy due to thermal expansion, as determined by predicted and measured values of thermal forces in liquid and solid materials exposed to MW pulses. That sounds are mediated by pulse energy levels sufficient to raise tissue temperature only 5×10^{-6} C indicates that care must be exercised in classifying an effect as thermal or nonthermal on the basis of the level of temperature increase. (20 references)

0498 ACTION OF CORTI'S ORGAN AND THE COCHLEA: A NEW THEORY. *(E.)* Malcolm, J. E. (Roy. Air Force, Cent. Med. Establ., London, England). *Ann. N. Y. Acad. Sci.* 247, 219-231, 1975.

A model simulating the action of Corti's organ and the cochlea is described. It considers the labyrinth as a whole, based on a monoclinic crystal which is birefringent, rotates plane-polarized light, and is optically active. It is not necessarily at variance with direct observation although these observations may be interpreted differently. Increased cochlear electric potential, which represents stored energy, is associated with a mechanical translation of the basilar membrane and angular separation of Corti's rods and is effected by 'pumping' by the endolymphatic sac and the muscles that act on the auditory ossicles. The semicircular canals function as valves; the utricular and saccular macules form holograms and reflect the energy into the cochlear duct. Incoming acoustic waves excite dipole resonance and stimulate emission of a fraction of the stored energy; further amplication is effected by the hair cells, which, together with the tectorial membrane, behave like a transistor. These suggest a new theory of static balance and the action of Corti's organ: the labyrinth functions as a traveling wave maser of which the cochlea is the slow wave structure. Cochlear geometry itself effects resolution of incoming pitch. Corti's organ corresponds to the melatopes of the crystal, and the inter-rod angle is critical for any particular frequency, since it is related to the dispersion of the optic axes. (8 references)

Part III. Biochemical and Biophysical Effects

0499 MICROWAVE EFFECTS ON THE BLOOD-FORMING SYSTEM WITH PARTICULAR REFERENCE TO THE LYMPHOCYTE. *(E.)* Czerski, P. (Dep. Human Genet., Natl. Res. Inst. Mother Child, Warsaw, Poland). *Ann. N. Y. Acad. Sci.* 247, 232-242, 1975.

Three sets of experiments were performed to study the responses of blood and blood-forming systems to low levels of MW radiation. In the first, male CWF mice were used to determine the influence of MWs on the response of immunocompetent lymphocytes. The mice were irradiated for 2 hr daily with 2950 MHz pulsed MWs in far-field conditions at 0.5 mW/cm^2 mean power density. One hundred mice were exposed for 6 wk and 100 for 12 wk, 6 days/wk. After termination of exposure, the animals were immunized and 5 mice from each group were sacrificed on days 4, 6, 8, 12, and 20. Lymphoblast and plasmocyte percentages were determined, the immune response was measured, and serum hemagglutinins were estimated. Significant differences in immune response from controls were obtained in mice irradiated for 6 wk, but not in those exposed for 12 wk, indicating that the animals adapt to the MWs after a period of response. In the 2nd experiment, 12 rabbits were irradiated (2950 MHz, pulsed 1200 Hz, 1 μsec) 2 hr/day for 6 mon at 5 mW/cm^2. Peripheral blood was obtained each mon and lymphocyte cultures were counted. After an initial period in which the number of cells undergoing spontaneous lymphoblastoid transformation increased, the values returned to baseline with a 2nd increase one mon after irradiation terminated. In a 3rd series of experiments human lymphocyte suspensions were treated with 2950 MHz MWs for various periods at several power densities and the percentage of lymphoblastoid cells was determined. Preliminary results are poorly reproducible but suggest that *in vitro* exposure may induce lymphoblastoid transformation. These experiments indicate that studies of the response of the hematopoietic system to MWs may reveal subtle effects at low power densities. (18 references)

0500 THE EFFECT OF ELECTROMAGNETIC RADIATION ON THE HEMATOPOIETIC STEM CELLS OF MICE. *(E.)* Rotkovská, D. (Inst. Biophys., Czechoslovak Acad. Sci., Brno) and A. Vacek. *Ann. N. Y. Acad. Sci.* 247, 243-250, 1975.

The effect of whole body MW irradiation on hematopoietic cell populations and a comparison with the influence of external heat has been studied. Two-mon-old female C57Bl/10 mice were exposed to 100 mW/cm^2 2450 MHz radiation. Groups of 5 mice were irradiated for 5 min; rectal temperatures were measured before and after irradiation. Leukocyte and erythrocyte counts in peripheral blood and the number of cells in the femur and spleen were estimated. ^{59}Fe was administered into the spleen and bone marrow and followed until 20 days after irradiation or heating. The mice were sacrificed, spleens and femurs removed, and activities of individual organs were measured. Two waves of increase in leukocyte count occurred after irradiation: the first lasted until day 4 and the 2nd reached a maximum on day 6, returning to the initial level on day 7. Exposure to heat resulted in a rise in leukocyte count which persisted to day 7 with a maximum on day 4. Erythrocyte count was unaltered by irradiation and heat. ^{59}Fe incorporation decreased to 78% within 24 hr of irradiation, then increased to 250% on day 14. After heat exposure, ^{59}Fe incorporation increased initially, decreased during the 2nd and 3rd day, and returned to normal. Cell count decreased up to 72 hr after irradiation, then increased during days 4-7 in the spleen. No significant change was noted in the femur. The different effects of MWs and externally applied heat on hematopoietic stem cells suggests that alterations caused by high-intensity MW radiation are not related only to increased internal temperature. (9 references)

0501 THE EFFECT OF MICROWAVES (2450 MHz) ON ISOLATED RAT LIVER MITOCHONDRIA. *(E.)* Elder, J. A. (Exp. Biol. Lab., Natl. Environ. Res. Cent., Research Triangle Park, N.C.) and J. S. Ali. *Ann. N.Y. Acad. Sci.* 247, 251-262, 1975.

An *in vitro* study on the effects of 2450 MHz radiation on rat liver mitochondria exposed to power densities of 10 and 50 mW/cm^2 was performed. Temperature was maintained at < 4 C. Long-Evans rats fasted overnight. Liver mitochondria were isolated in 0.25 M sucrose and resuspended in sucrose to 50 mg/ml. Two ml of the suspension in a petri dish were placed in the exposure chamber at 0 C. At 0.5 hr intervals over a 2.5 hr period an aliquot of sample was removed and oxygen uptake measured. Aliquots of control sample kept at 0 C were measured alternatively. The experiment was repeated 3 times at each exposure. Oxygen consumption was measured at 25 C. Results showed no differences in respiratory control of mitochondria at either exposure level as compared to control. ADP/O ratios were in good agreement with the normal values, and there was no alteration in response of mitochondria to calcium ions. A statistical analysis ($p \leq 0.05$) found no differences between slopes of irradiated and control samples. Thus, no effects of MW radiation were found on the molecular processes of substrate oxidation, electron transport, oxidative phosphorylation and calcium transport during 3.5 hr exposures to 10 and 50 mW/cm^2 power densities. (19 references)

0502 EFFECT OF MICROWAVES ON CELL FUNCTION AND VIRUS REPLICATION IN CELL CULTURES IRRADIATED IN VITRO. *(E.)* Szmigielski, S. (Inst. Aviat. Med. Dep. Med. Microbiol., Univ. Med. Sch., Warsaw, Poland), M. Luczak, and M. Wiranowska. *Ann. N.Y. Acad. Sci.* 247, 263-274, 1975.

Morphological and cytochemical studies were performed on WISH cells 1, 24, and 48 hr after *in vitro* radiation with 3 GHz EM waves. Cultures infected with parainfluenza 3 virus (10^6 $TCID_{50}$ /ml) 1 or 2 hr after irradiation, or irradiated with MWs 2, 8, or 16 hr after virus infection, were examined for morphological changes and virus multiplication at

48 hr postinfection. The reduction rate of nitro blue tetrazolium in WISH cells 1 hr after irradiation at 20 mW/cm^2 was markedly decreased. Only 10-15% of the cells showed large granules and/or formazan deposits and diffuse staining, compared with 50-70% of control cells. The percentage of cells with succinic dehydrogenase activity declined markedly in irradiated cultures. By 24 hr postirradiation, cell function had partially returned to normal. The reduction rate of nitro blue tetrazolium increased in cells 24 hr after irradiation at > mW/cm^2 and returned to normal by 48 hr. At both 20 and 5 mW/cm^2, the percentage of nigrosine-stained cells was comparable to control values. Virus infection was accompanied by an increase in the number of nigrosine-stained cells, a decline in nitro blue tetrazolium, and an increase in succinic dehyrogenase activity. Irradiation at 5 mW/cm^2, but not at 20 mW/cm^2, stimulated virus multiplication regardless of whether exposure occurred before or after virus infection. This increase in virus multiplication was accompanied by a significantly higher reduction of nitro blue tetrazolium, particularly in cells infected before irradiation. Stimulation of oxidative metabolism by this radiation dose may be the cause of increased virus multiplication. Since WISH cells react differently to 5 and 20 mW/cm^2 power densities, quantitation of the energy absorbed is a problem. Nevertheless, continuous cell-line monolayers *in vitro* are an attractive model for studying the effects of MW radiation on cell metabolism. (14 references)

0503 EFFECT OF 10-CM (3 GHz) ELECTROMAGNETIC RADIATION (MICROWAVES) ON GRANULOCYTES IN VITRO. *(E.)* Szmigielski, S. (Inst. Aviat. Med., Warsaw, Poland). *Ann. N. Y. Acad. Sci.* 247, 275-281, 1975.

The effect of low level (1 mW/cm^2) MW fields on injury to the cell membrane and potassium efflux from erythrocytes after *in vitro* irradiation was determined. Pre-treated rabbit granulocytes were isolated from the peritoneal cavity and suspended in heparinized saline. The percentage of granulocytes was measured and suspensions containing at least 90% mature granulocytes were exposed to 3 GHz EM waves (1 or 5 mW/cm^2) under far field conditions for 15, 30, or 60 min. The percentage of dead cells was determined, phase-constant microscopy of living cells was performed, acid and alkaline phosphatase and lysozyme activities were measured, and formazan concentration was determined in nitro blue tetrazolium solution and pyridine. There was an increased percentage of dead cells only in suspensions exposed to 5 mW/cm^2 radiation for 30 or 60 min. Under phase-constant microscopy many vacuoles stained with neutral red were visible in cells exposed to 5 mW/cm^2 for 30 or 60 min. Acid phosphatase and lysozyme were liberated from granulocytes at either power density and were dependent on both time and dose. After irradiation at 5 mW/cm^2 the number of nitro blue tetrazolium reducing granulocytes was elevated at 15 and 30 min followed by a rapid decline at 60 min exposure. These observations suggest that specific cellular injury, which is dose and time dependent, is produced *in vitro* by low level radiation and that MW radiation disturbs cellular membranes. The stimulation of energetic metabolism seems to be a reversible disturbance whereas the decline in nitro blue tetrazolium reduction and liberation of lysosomal enzymes are symptoms of irreversible injury. (21 references)

0504 A COMPARISON OF THERMAL AND RADIO-FREQUENCY EXPOSURE EFFECTS ON TRACE METAL CONTENT OF BLOOD PLASMA AND LIVER CELL FRACTIONS OF RODENTS. *(E.)* Rupp, T. (Radiobiol. Div., U. S. Air Force Sch. Aerosp. Med., Brooks Air Force Base, Tex.), J. Montet, and J. W. Frazer. *Ann. N.Y. Acad. Sci.* 247, 282-291, 1975.

Present MW exposure standards in the U. S. are primarily based on an estimation of the thermal insult involved; to determine the extent of damage, the nature of the biochemical changes induced is important. Experiments were run to determine changes in plasma metal content and to compare changes induced by MW exposure to those brought about by thermal exposure. Male Sprague-Dawley rats were exposed for 45 minutes in a hot air drying oven to external temperatures sufficient to raise body temperature to 40, 42, and 45 C. The animals were anesthetized, blood was withdrawn and the liver was excised, weighed, homogenized and centrifuged. Various aliquots of the liver and blood plasma were tested for Zn, Fe, Cu, Ca, and Mg. Experimental animals were exposed to RF radiation (H-field ~ 77 A/m, E-field ~ 30 kV/m) in the USAFSAM HF band exposure system; core temperatures were matched with those produced thermally and the same blood and liver tests were run. Elevation in plasma iron content was found after exposure, with half the rise coming from loss by the liver. A small increase in globulin was noted after RF exposure but not after thermal exposure. The plasma content of Mg, Ca, and Zn did not change appreciably although total and heavy particle content of Mg decreased appreciably after RF exposure. The alterations noted seemed to take place only in extreme fields with a large thermal component. Thus, some thermally produced changes in divalent metal distribution in rat liver can be duplicated by application of high-intensity RF fields. (12 references)

0505 EFFECTS OF ELECTROMAGNETIC FIELDS ON MICROSOMAL ATPase AND MITOCHONDRIAL OXIDATIVE PHOSPHORYLATION. *(E.)* Straub, K. D. (VA Hosp., Little Rock, Ark.) and P. Carver. *Ann. N. Y. Acad. Sci.* 247, 292-300, 1975.

Experiments were performed to determine the effects of electric and EM fields on Na-K ATPase from guinea pig brain, oxidative phosphorylation in rat liver mitochondria, and frog skin ion transport. Membrane-bound Na-K ATPase was prepared from guinea pig brain and assayed by measuring the release of inorganic phosphate from ATP. Mitochondria were assayed at 22 C in a Clark oxygen electrode and ADP/O ratios

were calculated. Potential difference and short circuit current were measured on the ventral skins of grass frogs. CW MW power (maximum 2-5 mW/cm^2) was generated by backward wave oscillators of appropriate frequency. Frog skin was very sensitive to low frequency currents; after 10 sec exposure to 20 Hz at a current density of 400 μA/cm^2, skin potential increased 200% while short circuit current increased 35%. Three effects were noted: at low density there is an increase in potential difference, with little change in the short circuit current; this signifies a decrease in passive ion flux without change in active transport. At higher current density, increases which occur in both potential difference and short circuit current could be due to active ion transport and/or decreased passive ion movement. Very high densities cause irreversible damage to membrane structures with a decrease in ion transport and increase in passive permeability to ions. No effects were seen on microsomal preparations from guinea pig brain for either Na-K ATPase or ADP/O ratios. No effects were noted on rat liver mitochondria exposed in low frequency ac fields or at MW frequencies. For MW exposure, the incident power density may be less than that calculated due to experimental conditions incurred. However, there was no evidence of MW effects at equivalent power levels ≈ 1-2 mW/cm^2. (8 references))

0506 EFFECTS OF MICROWAVE RADIATION ON ENZYMES. *(E.)* Yeargers, E. K. (Biol. Dep., Georgia Inst. Technol., Atlanta), J. B. Langley, A. P. Sheppard, and G. K. Huddleston. *Ann. N.Y. Acad. Sci.* 247, 301-304, 1975.

Enzymes have been chosen as the test subject of experiments to investigate their sensitivity to MW energy and to apply these effects to living organisms as a whole. Most enzymes are characterized by a high sensitivity to heat so tests were run to compare the results of conductive and convective heating with the results of MW absorption and its resultant heating effect. Any differences should be due to effects which are uniquely those of MW radiation. A 2450 MHz Litton Industries magnetron was used as the source of MW energy and the power level was controlled by a high power attenuator. Lysozyme and trypsin (10^{-6} M solutions) were heated at MW levels of 50 to 300 W until a specific temperature between 30 and 95 C was reached. The desired temperature was maintained for 1.5 hr then the samples were permitted to cool to room temperature and assayed. An unheated control was also assayed. The curves for the MW and conventionally heated samples were essentially parallel with no discernable differences in enzyme performance after 50 independent measurements. Thus, no differences in enzyme activity were observed as a function of the heating methods. (No references)

0507 ACUTE STAPHYLOCOCCAL INFECTIONS IN RABBITS IRRADIATED WITH 3 GHz MICROWAVES. *(E.)* Szmigielski, S. (Inst. Aviat. Med. Natl. Inst. Hyg., Warsaw, Poland), J. Jeljaszewicz, and M. Wiranowska. *Ann. N.Y. Acad. Sci.* 247, 305-311, 1975.

Experiments were performed on 10 adult rabbits to examine granulopoietic reaction after long-term exposure to nonthermal MW radiation concurrent with acute staphylococcal infection. Five rabbits were exposed for 6 wk and 5 for 3 mo in an anechoic chamber to 3 GHz EM waves in far field conditions. Irradiation was at 3 mW/cm^2 for 6 hr/day. After exposure, animals were infected i.v. with virulent *M. pyogenes*, variety. Before and 4, 6, 10, and 14 days post infection functional tests of granulopoiesis were performed on the 10 test rabbits and 5 controls. In controls the number of leukocytes and granulocytes in peripheral blood increased during the entire observation period; a higher percentage of young granulocytic cell forms was found in bone marrow 10-14 days after infection. Irradiated animals differed from controls in behavior, granulopoietic reaction differed markedly, and the clinical course of the disease was more serious. Rabbits after 6 wk exposure displayed stronger leukocytosis and granulocytosis 4 and 6 days after infection, followed by a dramatic drop below normal values 10 and 14 days after infection. There was also a decline in the bone marrow reserve pool and reduced lysozyme activity during the entire observation period. Animals exposed for 3 mon displayed much lower leukocytosis and granulocytosis after infection as compared to controls despite similar pre-infection values. There was a relative increase in percentage of younger granulocytic cell forms. Thus prolonged exposure to low levels of MWs resulted in decreased production of mature granulocytes, but a proper level of granulocyte numbers was maintained in the peripheral blood and impaired reactivity of the system occurred only after action of stimulatory agents. (21 references)

0508 DISCUSSION PAPER: IRRADIATION OF BOVINE SERUM ALBUMIN WITH A CROSSED-BEAM EXPOSURE-DETECTION SYSTEM. *(E.)* Allis, J. W. (Exp. Biol. Lab., EPA, Research Triangle Park, N.C.). *Ann. N.Y. Acad. Sci.* 247, 312-322, 1975.

Bovine serum albumin (BSA) was used to determine whether S-band MW radiation has a direct interaction with proteins and whether there is a dependence on protein flexibility. By means of UV difference spectroscopy, changes in the environment of UV-absorbing amino acids (tryptophan, tyrosine, and phenylalanine) were studied as a function of molecular flexibility during MW perturbation. Difference spectra of BSA were run with 2.45 GHz radiation (absorbed dose, 30, 70, and 100 mW/g) for deionized protein and defatted protein. Difference spectra were also run with 1.70 GHz radiation (37 and 54 mW/g) for deionized protein only. Measurements were made at wavelengths from 300-240 nm (330-240 nm for defatted BSA), five pH values (4.5, 3.7, 3.0, 2.5, and 2.0) and sample temperatures of 25-26 to 34-35 C. Whether obtained just after irradiation was begun or at 30 min all difference spectra yielded uniform results: no differences were noted in samples irradiated by MWs at either frequency. In addition, there were no differences between irradiated and un-

irradiated samples. As a further control, acrylamide gel electrophoresis experiments were done on BSA from the irradiated sample, BSA from the reference chamber of the spectrophotometer, totally untreated BSA, and BSA heated to 75 C for 15 min. No difference was observed except in the protein heated to 75 C, which showed marked deterioration. It is concluded that protein flexibility is not a sensitive parameter in the S-band region of the MW frequency spectrum; furthermore the relaxation of bound water at the surface of proteins excited by these frequencies is not significant for protein structure. (12 references)

0509 DISCUSSION PAPER: RAMAN SPECTROSCOPY OF MOLECULAR SPECIES DURING EXPOSURE TO 100-MHz RADIO-FREQUENCY FIELDS. *(E.)* Klainer, S. M. (Res. Eng. Div., Block Eng., Inc., Cambridge, Mass.), and J. W. Frazer. *Ann. N.Y. Acad. Sci.* 247, 323-326, 1975.

The use of lazers as light sources for Raman spectrometers allows direct observation of the effects of applied fields on polar molecules in aqueous solution. These molecules can orient themselves over a frequency range that depends on charge distribution, solvent viscosity, and molecular weight. Ten percent solutions of glycine, ATP, *E. coli* tRNA, and electrophoretically homogeneous chymotrypsin were prepared. An argon lazer was used and measurements were made at 0.4880 μm. Constant temperature was maintained. When RF fields were applied, no pertubations of glycine or ATP spectra were found. *E. coli* tRNA lost several peaks associated with intramolecular hydrogen bonding after 1 hr of exposure and power feed of 8 W. In chymotrypsin the progressive loss of prominent peaks at input power of 3 W and 4 W was noted in the vibrational spectra of the molecular backbone. At 5 W the solution became very turbid. Alterations in the Raman spectra may reveal information usually found in dielectric dispersion spectra and may show effects of applied fields on the tertiary structure of large molecules. (5 references)

Part IV. Effects on Genetics and Development

0510 GENETIC CONTINUITY AND METABOLIC REGULATION AS SEEN BY THE EFFECTS OF VARIOUS MICROWAVE AND BLACK LIGHT FREQUENCIES ON THESE PHENOMENA. *(E.)* Webb, S. J. (Dep. Bacteriol., Univ. Saskatchewan, Saskatoon, Canada). *Ann. N.Y. Acad. Sci.* 247, 327-351, 1975.

Experiments were performed to determine the time at which the synthesis and activity of β-galactosidase occur in *Escherichia coli* B cells, the effects of nutrition on mutation by 320-410 nm light, and the action of MWs on metabolic events in bacterial and *mammalian cells*. The enzyme appeared in cells after 10 min incubation in amino acid-lactose medium and reached its maximum level 10 min later. ^{14}C-carbon dioxide did not appear before 40 min, approximately 20 min before the cells underwent their first cell division. In cells induced in a succinate-NH_4Cl-lactose medium, the enzyme did not appear until after 155 min of incubation, and ^{14}C-carbon dioxide did not appear before 155 min, approximately 10 min before the first cell division. After the first and second divisions, only 50 and 75-80% of the daughter cells, resp., contained the new metabolic systems conducive to new nutritional environments. Only when ^{14}C-lactose respiration began (25-40 min after the appearance of β-galactosidase) were cells able to proliferate on NH_4+ salts-lactose agar. In addition, glucose acted as a competitive inhibitor only when added to lactose induction medium prior to enzyme appearance. Study of mutations induced by 320-410 nm light in synchronized lag phase cultures of *E. coli* demonstrated that an absorbing chromatophore, present in the membrane respiratory chain, traverses the DNA and sequentially contacts each gene at a definite time in the life of a cell. The time lapse between successive contacts depends on nutrition, particularly carbon, and is between 30-45 min. Data for bacterial cells exposed to a field density of 10-50 mW/cm^2 showed that two sets of frequencies affected protein and DNA synthesis of cells in glucose-amino acid medium. In one set the frequencies are separated by integral multiples of 7 GHz; in the other, by 5 GHz. Both the frequencies absorbed and their separation are controlled by the nutrition supplied. All normal mammalian cells tested absorbed given MW frequencies between 50-90 GHz which influenced the rates of protein and DNA synthesis and which formed two series separated by 2.0 and 2.5 GHz, resp. The frequencies absorbed by tumor cells appeared to form 2, and perhaps 3, series separated by 1.0-2.0, 2.3, and 2.7 GHz, resp. As a given cell strain changed from highly tumorigenic to nontumorigenic, the strength of attenuation in the 2.3 and 2.7 GHz series of frequencies absorbed decreased and that of frequencies in the 2.5 GHz series occurred or increased. In an effort to explain these observations, a new concept of cell metabolism and its genetic control is presented in detail. (50 references)

0511 EFFECTS OF NONIONIZING ELECTROMAGNETIC RADIATION ON SINGLE-CELL BIOLOGIC SYSTEMS. *(E.)* Blackman, C. F. (Exp. Biol. Lab., Nat. Environ. Res. Cent., Research Triangle Park, N.C.), S. G. Benane, C. M. Weil, and J. S. Ali. *Ann. N.Y. Acad. Sci.* 247, 352-366, 1975.

The effect of MW irradiation on growth of two strains of *E. coli* was investigated with two environmental control chambers. A large chamber provided temperature regulation to ± 0.5 C and was used for free-field CW irradiations at 1.70 or 2.45 GHz. A small chamber providing temperature regulation to ± 0.1 C was used for far- and near-field irradiations at 68-74 GHz. Exposure of strain Cs, grown in tryptone broth at 32 C, to 2.45 GHz (power density 0.005, 0.5, 5.0, 50 mW/cm^2) did not inhibit cell growth, as shown by comparison of the ratios of the number of cell doublings for MW treated samples with those for control samples. Slight (0.2-0.3 C) radiative heat losses were found to affect *E. coli* growth. No MW-induced inhibition of log or lag phase cells re-

sulted from irradiation in tryptone broth at 25 C. Similarly, in glucose-minimal salts medium, there was no inhibition of log phase cells at 32 or 25 C or of lag phase cells at 32 C. Experiments with ϕX 174 virus and strain Cs indicated no MW induced inhibition of virus growth. Strain WWU cells (log phase, grown on glucose Bl, irradiated at 30 C) were exposed over the range 1.70-74 GHz. The irradiated samples grew sufficiently beyond one cell doubling to suggest no radiation induced inhibition. Results for cell growth at 35 C after carbon and nitrogen source changes also failed to demonstrate growth inhibition. In all experiments, the only obvious effect of MWs was enhanced cell growth, which can be attributed solely to slight temperature rises in the test system. (20 references)

0512 EFFECTS OF ELECTROMAGNETIC RADIATION ON IMPLANTATION AND INTRAUTERINE DEVELOPMENT OF THE RAT. *(E.)* Dietzel, F. (Dep. Nucl. Med., Justus Liebig-Univ. of Giessen, Germany). *Ann. N. Y. Acad. Sci.* 247, 367-376, 1975.

The effects of HF treatment of the abdomen on the intrauterine development of 7800 embryos of 749 pregnant rats were evaluated. The rats were treated once for a short time with a SW field (27.12 MHz) between the 1st and 16th day of pregnancy. The EMR doses were measured thermally by continuously monitoring rectal temperature. Electric power of 50, 70, and 100 W was used. The fetuses were sectioned on day 20, weighed and examined for external visible malformations and spinal and skeletal defects. Preimplantation loss was calculated. HF effects were dependent on the pregnancy phase with the type of malformation dependent on the day of pregnancy at time of exposure. Early exposure usually resulted in death of the embryo while later exposure was dangerous due to heat accumulation in the amnionic sac which is not well perfused. The frequency of malformations and abortion depended on the intensity of radiation; however, a lower threshold at which malformations will occur was found than previously reported. A significant rise was observed only when thermal effects occur. In studies on superficial experimental tumors a much greater effect was found to occur with nonionizing than ionizing radiation, indicating that HF radiation may eventually be used to therapeutically treat malignant tumors. (20 references)

0513 SOME EFFECTS OF EXPOSURE OF THE JAPANESE QUAIL EMBRYO TO 2.45-GHz MICROWAVE RADIATION. *(E.)* McRee, D. I. (Nat. Inst. Environ. Health Sci., Research Triangle Park, N. C.) P. E. Hamrick, J. Zinkl, P. Thaxton, and C. R. Parkhurst. *Ann. N. Y. Acad. Sci.* 247, 377-390, 1975.

The influence of 2450 MHz CW radiation at normal incubation temperature on cellular differentiation systems of Japanese quail embryos (*Coturnix coturnix japonica*) was studied. The quail was selected for its smaller egg size and shorter development time as compared to the chicken. Gross malformations and hematologic parameters were used to determine biological effects of radiation exposure. Six groups of 57 eggs each were irradiated at a power density (30 mW/cm^2) that would maintain temperature during exposure to the same as that of the incubator (37 C). Irradiation lasted for 4 hr in a 40% humidity environment. Groups 1, 2, 3, 4, and 5 were irradiated for 4 hrs each at the end of days 1, 2, 3, 4, and 5 of incubation, resp.; group 6 was exposed for 4 hr on each of the 5 incubation days. Control groups corresponding to each of the exposed groups were handled identically except for the actual irradiation. After exposure, test and control eggs were returned to the incubator to hatch. Two days after hatching began quail were weighed, decapitated, and examined for gross deformities. Blood samples were taken to determine hematocrit, RBC count, WBC count, hemoglobin, and differential WBC percentages. Weights for control and exposed birds were almost identical and differences were small for gross deformities. There were no striking differences in any blood studies for control or exposed groups. No gross malformations attributable to MW irradiation were noted, suggesting that either quail embryos are less sensitive than chicken embryos to radiation, or heat augmented the effects of MWs in previous experiments. (14 references)

0514 EFFECTS OF ELECTROMAGNETIC FIELDS ON FECUNDITY IN THE CHICKEN. *(E.)* Krueger, W. F. (Dep. Poultry Sci. Electr. Eng., Texas A & M Univ., College Station), A. J. Giarola, J. W. Bradley, and A. Shrekenhamer. *Ann. N. Y. Acad. Sci.* 247, 391-400, 1975.

An evaluation of CW low power VHF and UHF near zone exposure, including ELF E-fields and magnetic fields, on fecundity in the chicken was made. One cock and 4 inbred hybrid females constituted each of the 6 groups of birds used. One group served as controls and the others were exposed as follows: (1) to a 260 MHz UHF field that decreased from 100 to 4 mW during the experiment [E^2/η (square of the E-field strength/intrinsic impedance of free space) decreased from 125 to 5 μW/cm^2]; (2) to a 915 MHz UHF field with available power of 800 mW for 2.5 wk, 0 for 1 wk and 200 mW for the remainder of the experiment (E^2/η = 100 μW/cm^2, 0, and 250 μW/cm^2, resp.); (3) to a 2.435 GHz MW field excited by a source with an available power of 800 mW (E^2/η = 1000 μW/cm^2); (4) to a 60 Hz ELF E-field with an electric potential of 950 V; and (5) to a 60 Hz low-frequency magnetic field with a mean value of 1.4 G. The chickens were exposed for 12 wk followed by a 4 wk nonexposure period. Daily egg production, feed intake, egg specific gravity, fertility, hatchability, abnormalities, and sex ratio data were collected on each group. Egg production rate decreased for all five groups during the 112 day test period, but hens exposed to UHF and VHF EM fields performed differently from the others. All birds except those exposed to the magnetic field adapted to their new environment after 6-8 wk exposure and egg production stabilized at the new value. Neither fertility nor hatchability was affected by the radiation. No evidence of a

change in sex ratio was seen except possibly in the magnetic field and no abnormalities attributable to the exposure were noted. Egg shell quality degenerated in the group exposed to 2.435 GHz MWs. (8 references)

0515 THRESHOLD EFFECTS OF MICROWAVE RADIATION ON EMBRYO CELL SYSTEMS. *(E.)* Pyle, S. D. (Dep. Electr. Eng., Univ. Colorado, Boulder), D. Nichols, F. S. Barnes, and E. Gamow. *Ann. N. Y. Acad. Sci.*, 247, 401-407, 1975.

Experiments to determine damage thresholds caused by pulsed MWs on biological systems and to improve understanding of the physical mechanisms associated with these thresholds were reported. Eggs of the zebra fish, *Brachydanio rerio*, were exposed to high PW MW fields at a low duty cycle to minimize heating. Maximum forward power available was ∿0.5 Mw (1 sec, 2.7 GHz, 20 pps). Zebra fish were chosen because they hatch quickly (4 days), are small, and are transparent enough for the developing embryo to be seen. Incubation, handling, and temperature control experiments were run. In MW irradiated embryos, injury appeared quickly as a small internal bulge which enlarged until it broke with all the embryonic material flowing into the chorionic space. In thermal control experiments, embryos appeared disorganized and opaque after 24 hr. The MW power levels which cause damage are unknown, but the qualitative differences between control and irradiated samples are significant. (1 reference)

Part V. Effects on Behavior

0516 INTRODUCTION: EFFECTS ON BEHAVIOR. *(E.)* Justesen, D. R. (VA Hosp., Kansas City, Mo.). *Ann. N.Y. Acad. Sci.* 247, 408-409, 1975.

To the extent that cognitive processes are part of an organism's reaction to physical events in the environment, a behavioral scientist is needed. In assessment of radiation effects on behavior, interdisciplinary effort is necessary between biologists, engineers and psychologists. In this session attempts were made to impart understanding of some of the technical language of experimental psychology. (1 reference)

0517 MICROWAVE DOSE-RESPONSE RELATIONSHIPS ON TWO BEHAVIORAL TASKS. *(E.)* Galloway, W. D. (Div. Biol. Eff., Bur. Radiol. Health, Rockville, Md.). *Ann. N. Y. Acad. Sci.* 247, 410-416, 1975.

On the assumptions that observed behavioral effects are due to the absorption of MW power within the CNS and that these effects will occur in a dose-related fashion, studies of MW effects on discriminative performance and upon the acquisition of behavior were conducted. Four rhesus monkeys were trained to perform discriminative tasks; they were exposed at various time intervals over a 9 mon period with integral dose rates of 5, 10, 15, 20, and 25 W of 2450 MHz CW radiation. There was no suggestion of a radiation induced effect upon performance at any exposure regimen. Two rhesus monkeys were trained at a repeated acquisition task for 39 days before radiation was initiated. Integral dose rates of 10, 15, 20, and 25 W were randomly administered at least twice during the 100 day irradiation series. Duration of radiation was 2 min or until convulsions began. Some evidence of a dose related effect upon performance was revealed, with irradiation at 25 W consistently producing performance deficits. The assumption that the amount of work done upon the CNS can be estimated from the amount of energy absorbed by the head of the subject and/or the assumption that this value would be related to behavioral effects shown are incorrect. No behavioral effects were observed at doses of less than 15 W, while at higher levels skin burns or convulsions resulted without reliably changing performance. Methods for direct measurement of power absorption *in vivo* must be developed before the relationship between CNS irradiation and behavioral changes can be elucidated. (6 references)

0518 PRELIMINARY INVESTIGATIONS OF THE EFFECTS OF LOW-LEVEL MICROWAVE RADIATION ON SPONTANEOUS MOTOR ACTIVITY IN RATS. *(E.)* Roberti, B. (Med. Biol. Lab. TNO, Rijswijk 2100, Netherlands), G. H. Heebels, J. C. M. Hendricx, A. H. A. M. de-Greef, and O. L. Wolthuis. *Ann. N.Y. Acad. Sci.* 247, 417-424, 1975.

Wistar rats (160-180 g) were used in experiments to monitor changes in spontaneous motor activity with exposure to low-levels of MW radiation. X-band CW radiation of 10.7 GHz, S-band CW radiation of 3 GHz, and S-band pulsed radiation of 3 GHz were used at 1 mW/cm^2 power density. MWs at 10 GHz penetrate only a few mm so effects must be due to influences on superficial structures such as skin receptors; at 3 GHz radiation penetrates several cm which can affect the CNS and deep organs in the rat. One group of rats was exposed to each type of radiation for 185 hr and a 4th group was exposed to 3 GHz PW radiation for 17 days. Spontaneous motor activity was measured electronically by dividing movements made by the rat when placed between 2 horizontal metal plates into 6 classes, including rearing, time in upright position, and horizontal respiratory movements. Spontaneous motor activity was measured at the end of each irradiation period, and in the 17 day exposure was also measured after the 5th and 12th days. No significant differences were seen between irradiated and control animals; no deleterious effects of MW radiation were detected. (11 references)

0519 EFFECTS OF LOW-LEVEL MICROWAVE RADIATION ON BEHAVIORAL BASELINES. *(E.)* Thomas, J. R. (Naval Med. Res. Inst., Bethesda, Md.), E. D.

Finch, D. W. Fulk, and L. S. Burch. *Ann. N. Y. Acad. Sci.* 247, 425-432, 1975.

Changes in behavior of animals conditioned to respond to multiple schedules of reinforcement after exposure to low levels of MW radiation were observed. Four male Sprague-Dawley rats maintained at 80% of their free feeding weights were trained by the method of successive approximation to press levers to yield food pellets. They were then exposed to a multiple fixed-ratio, differential reinforcement of low rate (mult FR DRL) schedule for at least 60 sessions before experimental manipulation. The rats were irradiated with 2860 and 9600 MHz pulsed radiation and 2450 MHz CW radiation for 30 min under far-field conditions before experimental sessions 1-2 days/wk. Both CW and PW radiation at all frequencies produced changes in ongoing behavior. There was a marked decrease in response rate associated with the FR schedule and an increase in response rate associated with the DRL schedule. Responding also increased during time-out periods. Results indicate that low-level MW radiation produces effects on the CNS as evidenced by behavioral changes and these changes are influenced by interactions of the organism with the environment. (4 references)

0520 NEURAL FUNCTION AND BEHAVIOR: DEFINING THE RELATIONSHIP. *(E.)* Frey, A. H. (Randomline, Inc., Huntingdon Valley, Penn.), S. R. Feld, and B. Frey. *Ann. N. Y. Acad. Sci.* 247, 433-439, 1975.

The effects of PW and CW energy on behavior and brain permeability were studied in 2 sets of experiments. In the first, pulsed, CW and sham illumination effects on rats in a shuttle box were compared. One half of the box was shielded from RF energy. The pulsed radiation (1.2 GHz, 0.5 msec, 1000 pps) had a peak power level of 2.1 mW/cm^2 and average power density of 0.2 mW/cm^2; CW average power density was 2.4 mW/cm^2. The power densities selected were close to the lowest perceptible. Eighteen female Sprague-Dawley rats were randomly assigned to one exposure group and exposed 30 min/day for 4 days. No significant differences were found after 2 days, but differences were significant the last 2 days with the pulse-illuminated group spending 32% of their time in the unshielded half of the box, the sham spending 52%, and controls 64%. The differences between pulsed *vs* sham and pulsed *vs* CW groups were statistically significant. This is a behavioral technique which differentiates between pulsed and CW exposure and provides the potential for relating behavioral changes to brain change. In the second experiment, sodium fluorescein, which binds to serum protein when injected into the bloodstream, was used to study brain barriers. Ninety Sprague-Dawley rats were illuminated with MW radiation under the 3 exposure conditions used in the first experiment. They were then injected with the dye, allowed to equilibrate for several minutes, the animal was exsanguinated, and the brain was removed and embedded in gelatin. Fluorescence, which indicates alteration in the permeability of brain tissue barriers, was generally seen at the diencephalon level of the brain. Effects in the pulsed condition were significantly different from effects in the CW condition and both were different from control. The results indicate that irradiation of a small mammal with low power RF energy affects the brain barrier; it is not possible to conclude that the observed effect was direct, as illumination was not confined solely to the brain. An association is indicated between behavioral modification and brain permeability change when similar RF parameters are employed. (1 reference)

0521 BEHAVIORAL EFFECTS OF PULSED MICROWAVE RADIATION. *(E.)* Hunt, E. L. (Battelle, Pacific Northwest Lab., Richland, Wash.), N. W. King, and R. D. Phillips. *Ann. N. Y. Acad. Sci.* 247, 440-453, 1975.

Three sets of experiments were performed to study effects of pulsed MW radiation on exploratory activity, swimming, and discrimination performance on a vigilance task. Young adult male Wistar rats were irradiated or sham irradiated with pulsed 2.45 GHz MWs (120 pulses/sec) for 30 min in a multimode resonating cavity. Absorbed dose rates were 6 and 11 mW/g. In investigating effects of exploratory activity, rats were exposed and then placed in an activity apparatus and allowed to explore freely for 1-2 hr. In parallel tests animals were held for one hr postirradiation before activity tests were started to determine whether activity was related to elevation in body temperature produced by the radiation. Immediately after treatment, mean temperature was 40.3 C in exposed rats and 38.6 C in controls; one hr later values were 37.8 C and 38.0 C, resp. In both series of experiments exposed animals exhibited less activity than controls; activity level of controls decreased finally to the same level as irradiated animals. There was no evidence that one hr postirradiation delay attenuated the radiation effect, indicating that the decreased activity level was not directly related to transient hyperthermia produced by MW heating. In swimming performance experiments, trained rats were tested on a repetitive swim task immediately after 30 min exposure at 6.3 mW/g or 24 hr after exposure at 11 mW/g. All exposed animals exhibited a reduction in swimming speed late in the test resulting from a loss of capacity due to fatigue. To test exposure effects on performance of a complex discrimination task, trained rats were tested for 30 min immediately after irradiation at 0, 6.5, and 11 mW/g, and over a 5 day period with a series of irradiation tests. Although animals missed or ignored presentations of positive stimuli immediately after irradiation at either dose rate, a rapid rate of recovery continued throughout the test and was complete for the 6.5 mW/g exposure by the middle of the test period, indicating that performance loss was directly related to MW-induced hyperthermia. MW effects reflected alteration in performance rather than interference with trained skills as both swimming proficiency and accuracy in discrimination response were retained without retraining after nearly lethal irradiation. (15 references)