tate dehydrogenase performed the intermediate steps and were always present in excess so that the activity of ATPase was rate controlling. No statistical differences in enzyme activities were obtained between irradiated and control samples at any modulation frequency for eith enzyme.

5407 EFFECTS OF MICROWAVE RADIATION ON ERYTHROCYTE MEMBRANES (MEETING ABSTRACT). *(Eng.)*
Liu, L-M.; Cleary, S. F. *In: Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves.* Sponsored by The International Union of Radio Science & The U.S. Committee for URSI, held at Airlie, VA on October 30, 1977-November 4, 1977: pp. 103; 1977. (0 refs)

Rabbit erythrocyte suspensions were irradiated at room temperature (23 C) with S-band microwaves in a waveguide irradiation chamber for 3 hr or less. The release of K^+ ions, of hemoglobin, and the osmotic fragility of red cells were used to determine the effects of microwave irradiation on the erythrocyte's membrane. At 3.0 GHz and a power density at the center of the waveguide that was equivalent to a free field power density of 10 mW/cm^2, the maximum rise of temperature in the irradiated sample was 2.6 C during a 3-hr exposure. There was no difference in K^+ flux, hemolysis, or osmotic fragility between the microwave irradiated sample and the conventionally heated sample, even-though both were heated to the same temperature for the same duration. At an equivalent power density of 58 mW/cm^2, the maximum rise of temperature of the erythrocyte suspension was 15 C (i.e., from 23 to 38 C) and the percentage release of K^+ ions from the irradiated samples was slightly higher than that from cells heated in a water-bath at the same temperature. The difference was not statistically significant at the 5% level as determined by a *t*-test. The same procedure was used to determine the effects of 2.45-GHz and 3.95-GHz microwaves. No apparent effect on permeability of the erythrocyte's membrane was found. Data from studies that involved shorter exposure times, higher power levels, ouabain-treated cells, erythrocytes of species other than the rabbit, and aged red cells also are reported.

5408 INJURY OF CELL MEMBRANES IN NORMAL AND SV_{40}-VIRUS TRANSFORMED FIBROBLASTS EXPOSED IN VITRO TO MICROWAVE (2450 MHZ) OR WATER-BATH HYPERTHERMIA (43°C) (MEETING ABSTRACT). *(Eng.)*
Janiak, M.; Szmigielski, S. *In: Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves.* Sponsored by The International Union of Radio Science & The U.S. Committee for URSI, held at Airlie, VA on October 30, 1977-November 4, 1977: pp. 104; 1977. (0 refs)

Mouse 3T3 fibroblasts and SV_{40}-virus transformed mouse-3T3 fibroblasts (SV-3T3) were heated in a water bath or by 2,450-MHz microwaves to 40 or to 43 C. At 15-30 min intervals during and after heating, permeability of cell membranes was evaluated. In other experiments the cells were heated for various periods of time (30-120 min); injury of cell membranes and reversibility were evaluated at different times after exposure. Heating of cells to 43 C resulted in a rapid drop of ouabain-sensitive influx of 86-Rb, followed by decreased binding of ^{3}H-ouabain. These phenomena were observed in SV-3T3 cells after 5-10 min of heating, while in normal 3T3 cells, 20-25 min was required to exert the same effect. The changes in active transport of potassium were fully reversible, but when heating was continued, the cell membrane was irreversibly damaged and became permeable to large molecules. Cells maintained at 40 C for 4 hr did not exhibit increased permeability to large molecules or increased release of ^{51}Cr. No significant differences were observed in the sequence and time-course of cell-membrane injury between cells heated in a water bath and those heated in the microwave field. It is concluded that inhibition of active transport of potassium, the most early disturbance of metabolism found in cells heated to 43 C, plays a significant role in the mechanism of cell injury and inhibition of growth rate.

5409 A COMPARATIVE STUDY OF THE ACTION OF TWO TYPES OF MICROWAVE IRRADIATION ON LIPID METABOLISM IN MICE (MEETING ABSTRACT). *(Eng.)*
Deficis, A.; Dumas, J. C.; Laurens, J.; Plurien, G. *In: Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves.* Sponsored by The International Union of Radio Science & The U.S. Committee for URSI, held at Airlie, VA on October 30, 1977-November 4, 1977: pp. 105; 1977. (0 refs)

It was previously established that continuous wave (CW) irradiation of the mouse in a cavity at frequencies between 2.35 and 2.50 GHz increases its level of serum triglycerides. The experiments were extended to the free-field condition where mice were exposed in an electrically anechoic chamber to 2.45-GHz CW microwaves. The same effect on serum triglycerides was observed. In this study, the effects of both modes of irradiation were studied using 2-mo-old male DBA mice; 60 animals were irradiated in cavities; 94 were irradiated in the anechoic chamber. Duration of exposure was 60 hr; 126 controls were used. Measured or extrapolated root mean square power densities ranged from 3-4 (±3) mW/cm^2. Measurements of body temperature revealed no change between pre- and post-exposure readings. The levels of serum triglycerides of irradiated mice were significantly higher than those of controls, but the elevations were highest when irradiation took place in the free field. Levels of β-lipoproteins were correlated with those of the serum triglycerides.

5410 COMPARATIVE EFFECTS OF WATER BATH- AND MICROWAVE-INDUCED HYPERTHERMIA ON CELL SURVIVAL AND SISTER CHROMATID EXCHANGE (SCE) IN CHINESE HAMSTER OVARY (CHO) CELLS (MEETING ABSTRACT). *(Eng.)*
Livinston, G. K.; Johnson, C. C.; Dethlefsen, L. A. *In: Abstracts of 1977 International Symposium on the Biological Effects of Electromag-*

netic Waves. Sponsored by The International Union of Radio Science & The U.S. Committee for URSI, held at Airlie, VA on October 30, 1977-November 4, 1977: pp. 106; 1977. (0 refs)

To investigate possible extrathermal effects of 2,450-MHz microwave radiation, the response of Chinese hamster ovary (CHO) cells to equivalent thermal insults in a microwave field and in a water bath was compared. Experimental and control suspensions of synchronous cells in the log phase of growth were maintained at 44 C for 10, 20, 30, 40, 50, or 60 min. The microwave treatment consisted of inserting a culture tube with the CHO cells into a waveguide—the longest dimension of the tube parallel to the E field—and applying sufficient energy to maintain the desired temperature. Temperature-rise profiles were matched by monitoring experimental and control suspensions with the liquid-crystal optic-fiber temperature probe. Colony assays that were performed 8 days after hyperthermal treatments showed no significant differences in survival of cells. The sister chromatid exchange (SCE) frequency was also measured after 20-min hyperthermal treatments. Temperature of microwave irradiated cells was monitored with a thermistor perpendicular to the E field and in contact with the cell's monolayer. Hyperthermla elevated the SCE frequency above the control value (11.5 ± 0.38/cell) but there was no significant difference between cells treated in the water bath (17.3 ± 0.43) and in the microwave field (16.6 ± 0.69). No extrathermal effects of microwave radiation were detected in either of the experiments.

5411 EFFECTS OF MICROWAVES ON SPERMATOZOA AND OBSERVATION OF MOTILITY BY THE LASER-SCATTERING TECHNIQUE (MEETING ABSTRACT). *(Eng.)* Shimizu, H.; Sakurai, K.; Matsumoto, G. *In: Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves.* Sponsored by The International Union of Radio Science & The U.S. Committee for URSI, held at Airlie, VA on October 30, 1977-November 4, 1977: pp. 107; 1977. (0 refs)

The motility of spermatozoa of a sea chestnut *(Hemicentrotus pulcherrimus)* was studied after microwave irradiation by a laser light scattering technique. Two 6-ml samples of sperm from the same sea chestnut were prepared in test tubes. One sample was exposed to 2,450-MHz microwaves for 10 sec in a cavity; the temperature of the radiated sample was elevated by 5 C. The elevation of temperature of the control sample, which was heated by conventional means, was equivalent to that of the irradiated sample. Measurement of motility began immediately after heating and required about 1 min. The motility of sperm was essentially the same in both samples. The acute effect of microwaves on motility of spermatozoa appears to be due to thermal effects.

5412 FACIAL IRRADIATION OF THE FREELY RESPONDING *MACACA MULATTA* BY A 9.3-GHZ PULSED MICROWAVES: A LONG-TERM INVESTIGATION (MEETING ABSTRACT). *(Eng.)* McAfee, R.; Gordon, R.; May, J.; Elder, S. T. *In: Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves.* Sponsored by The International Union of Radio Science & The U.S. Committee for URSI, held at Airlie, VA on October 30, 1977-November 4, 1977: pp. 110; 1977. (0 refs)

A long-term investigation of the cataractogenic effects of microwave irradiation is reported together with an attempt to replicate certain behavioral and physiologic effects of microwaves in freely responding rhesus monkeys. The treated group (n = 24) and the control group (n = 75) were maintained in family groups in outdoor cages along with their infants. The adults individually entered an irradiation chamber and depressed a glass drinking tube that activated a microwave generator, which irradiated the monkey's face and eyes by energy from a 15-dB gain horn at 15-cm distance. Closure of the drinking-tube switch also allowed delivery of apple juice through the tube on a variable ratio schedule of reinforcement. Some monkeys worked 10 min for juice reward, while others worked for 20 min. The monkeys will be irradiated 4 days/wk for 52 wk, with follow-up for at least 2 additional years. The radiation source is an AN-CPN-6 radar beacon that is operated at 9.3 GHz in pulsed mode (0.5 μsec) at an averaged power density between 150 and 495 mW/cm^2. Power density is controlled by varying the pulse repetition frequency (i.e., 1,000 pulses/sec yields 150 mW/cm^2). Examinations of monkeys to date have revealed no evidence of deleterious ocular effects of the radiation after 40 sessions. Social behavior and the health and fecundity of the irradiated animals have not been altered. Behavioral changes, which might be reflected in rate of lever pressing, have not been apparent.

5413 HEMATOLOGIC AND SERUM-CHEMISTRY EVALUATION IN RATS EXPOSED TO 60-HZ ELECTRIC FIELDS (MEETING ABSTRACT). *(Eng.)* Ragan, H. A.; Pipes, M. J.; Kaune, W. T.; Phillips, R. D. *In: Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves.* Sponsored by The International Union of Radio Science & The U.S. Committee for URSI, held at Airlie, VA on October 30, 1977-November 4, 1977: pp. 126; 1977. (0 refs)

Hematologic and serum-chemistry evaluations were performed in twenty young adult female Sprague-Dawley rats exposed 21 hr daily for 15 or 30 days to a uniform, vertical 60-Hz electric field at an unperturbed field strength of 100 kV/m (± 5%). An equal number of rats was sham-exposed under identical housing and handling conditions. A third group of rats was maintained in the laboratory and served as caged controls. Hematologic evaluations were made using venous blood obtained from unanesthetized rats. For measures of clinical chemistry, the rats were anesthetized with ether prior to collection of blood from the heart; aliquots of serum then removed and quick-frozen until assayed. No significant differences among the three treatment

groups were observed on any hematologic endpoint including volume of packed red cells, red blood cell counts, hemoglobin concentrations, red cell corpuscular constants, reticulocyte concentrations, white blood cell counts, absolute distribution of leukocyte cell types, platelet concentrations, and bone marrow cellularity. No effects of electric field exposure were observed on the serum-chemistry endpoints including blood urea nitrogen, alkaline phosphatase, glutamic oxaloacetic transaminase, serum iron, total iron binding capacity, glucose-serum proteins, or the concentrations of albumin and the serum-globulin fractions as determined electrophoretically. The results of these studies using rigidly defined and controlled electric fields are compared with studies using much lower field strengths in which effects on hematologic and serum-chemistry variables have been reported.

5414 CHRONIC EXPOSURE OF PRIMATES TO ELF ELECTRIC AND MAGNETIC FIELDS (MEETING ABSTRACT). *(Eng.)* Grissett, J. D. *In: Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves.* Sponsored by The International Union of Radio Science & The U.S. Committee for URSI, held at Airlie, VA on October 30, 1977-November 4, 1977: pp. 127; 1977. (0 refs)

The physiologic and clinical effects of chronic exposure to electric and magnetic fields similar to those near the antenna of the U.S. Navy's proposed extremely low frequency (ELF) communications system were investigated. Body currents induced by this system were similar to those induced by some power distribution systems; therefore, the results of this experiment were of value in assessing the environmental impact of electric power technology. Thirty monkeys (*Macaca mulatta*) were exposed to a magnetic field of 0.2 milliteslas (mT), which is 10 times greater than the worst case conditions at the ELF antenna. The intensity of the electric field was 20 V/m, which is 2 times greater than that at the soil's surface near the grounding terminal and 300 times greater than that at the soil's surface along the antenna. Blood chemistry and metabolic data were collected at weekly intervals; comprehensive clinical examinations were given every 6 wk. Statistic analysis of the data was accomplished with a two-factor analysis of variance (ANOVA) with repeated measurements on one of the factors. The field-level factor contained exposure to the field and a non-exposed control. The analysis was designed to determine whether the experimental animals responded differently from controls across time and whether the overall data from one group differed from the other. The analyses are summarized and graphically presented with respect to data gathered after 22 mo of exposure.

5415 EFFECTS OF ELF FIELDS ON THE SLIME MOLD *PHYSARUM POLYCEPHALUM*: EVIDENCE FOR DEPRESSION OF CELLULAR FUNCTION AND FOR A TRANSFERABLE FACTOR (MEETING ABSTRACT). *(Eng.)* Greenebaum, B.; Goodman, E. M.; Marron, M. T. *In: Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves.* Sponsored by The International Union of Radio Science & The U.S. Committee for URSI, held at Airlie, VA on October 30, 1977-November 4, 1977: pp. 129; 1977. (0 refs)

The slime mold *Physarum polycephalum* was exposed to a variety of low level, extremely low frequency (ELF) fields for periods ranging from 2 mo-5 yr. Reproducible changes, significant at the $p < .05$ level were induced in several biologic parameters. Changes were generally about 10% in magnitude and consisted of a slowing of cellular processes; the cultures maintained their capacity to survive and reproduce. Cultures were exposed to 75-, 60-, and 45-Hz continuous wave (CW) and to 76-Hz MSK frequency-modulated fields at strengths ranging from 0.1 to 2.0×10^{-4} teslas (root mean square [rms]) and 0.04 to 0.7 V/m (rms). In most experiments both electric and magnetic fields were applied, but in some, only one or the other component was applied. Cultures were maintained in constant-temperature incubators that were equipped with identical magnetic field coils and other interior fittings. Growth vessels incorporated parallel plane stainless steel electrodes, which established the electric fields across the medium in which the slime mold was growing. In one experiment, however, all-glass vessels were used. Changes reported earlier during exposure of the mold to CW fields were again observed, including a lengthening of the cycle of mitotic nuclear division, lengthening of the period of spontaneous oscillatory streaming of the protoplasm and a decrease in respiration. The magnitude of effects and the rapidity of their onset were dependent on field intensity and frequency. Data are also presented from experiments in which cultures that combined *Physarum* from exposed and control cultures exhibited a mitotic cycle that was intermediate in length to that of the parent stocks. This was interpreted as evidence for some sort of transferable factor or deficit. Indirect measurements indicated that no apparent genetic differences were induced by exposure to ELF fields.

5416 BIOLOGICAL EFFECTS OF 60-HZ ELECTRIC FIELDS ON GROWTH AND METABOLIC STATUS OF RATS (MEETING ABSTRACT). *(Eng.)* Phillips, R. D.; Chandon, J. H.; Lang, L.; Hilton, D. I. *In: Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves.* Sponsored by The International Union of Radio Science & The U.S. Committee for URSI, held at Airlie, VA on October 30, 1977-November 4, 1977: pp. 130; 1977. (0 refs)

A comprehensive investigation of the possible biologic effects on small laboratory animals of exposure to 60-Hz electric fields is described. Systems have been built for chronic exposure of large numbers of rats and mice to uniform, vertical electric fields. A multidisciplinary research team is evaluating possible effects of electric-field exposure on hematology, serum chemistry, immunology, endocrinology, neurophysiology, central nervous system function and structure, pathology, cardiovascular function, bone growth and structure, reproduction, development, teratology, and growth.

In addition, the effects of electric field exposure on growth and metabolic status of rats are being assessed.

5417 ECG AND HEART-RATE RESPONSE OF RATS EXPOSED TO 60-HZ ELECTRIC FIELDS (MEETING ABSTRACT). *(Eng.)* Hilton, D. I.; Chandon, J. H.; Phillips, R. D. *In: Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves.* Sponsored by The International Union of Radio Science & The U.S. Committee for URSI, held at Airlie, VA on October 30, 1977-November 4, 1977: pp. 131; 1977. (0 refs)

Electrocardiograms (ECG) were recorded, and heart rates were determined for rats exposed to uniform 60-Hz electric fields at 80 kW/m. Heart rates and temporal characteristics of ECGs of rats exposed for 8 hr did not differ significantly from those of sham-exposed controls. Heart rate values of animals exposed for 40 hr (8 hr/day for 5 days) did not differ significantly from values obtained from controls.

5418 LONG TERM FOLLOW-UP *MACACA MULATTA* EXPOSED TO HIGH POWER LEVELS OF 15-, 20-, AND 26-MHZ RADIO-FREQUENCY RADIATION (MEETING ABSTRACT). *(Eng.)* Krupp, J. H. *In: Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves.* Sponsored by The International Union of Radio Science & The U.S. Committee for URSI, held at Airlie, VA on October 30, 1977-November 4, 1977: pp. 136; 1977. (0 refs)

The whole-body thermal response to radiation at high power densities (500-1,270 mW/cm^2) of 15-, 20-, and 26-MHz radio frequency radiation was measured in two groups of monkeys *(Macaca mulatta)* that totalled 18 animals. Each animal was exposed for 6 hr on at least two occasions. One or two yr later, standard clinical pathologic techniques were used to measure various hematologic and biochemical parameters. Physical examinations were performed, including slit-lamp examinations of the lens of the eye and opthalmoscopic examination of the fundus. No variations from normal values or conditions were found that could be attributed to the radiation.

5419 EFFECTS OF RADIO WAVES ON GROWTH, HEMATOLOGY AND HISTOLOGY OF MICE (MEETING ABSTRACT). *(Eng.)* Lin, J. C.; Nelson, J. C.; Ekstrom, H. E.; Nam, S. H. *In: Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves.* Sponsored by The International Union of Radio Science & The U.S. Committee for URSI, held at Airlie, VA on October 30, 1977-November 4, 1977: pp. 137; 1977. (0 refs)

The effects of single or repeated exposure to radio frequency (RF) energy on growth, hematology, and histopathology were investigated in male and female C3H mice. Animals were exposed at a power density of 1 mW/cm^2 in a rectangular exposure chamber at 148 MHz. For single exposures, eight groups of mice of differing age, from preweaned to mature, were exposed for 1 hr. For repeated exposures, animals were irradiated 1 hr/day, 5 days/wk, from day 4-7 postpartum for 10 wk. Animals were divided into two equal groups to serve as control and irradiated subjects. Body mass of animals was determined daily for 10 wk from the beginning of RF irradiation, and weekly thereafter. Groups of four mice were placed either in the control or in the radiation chamber at four standard locations. Blood was withdrawn from the tail vessels to make hemograms via micromethods. Formed blood elements were not affected to any significant extent by RF exposure. The comparable increments of body mass of irradiated mice and controls indicated that the animals remained in good health. Necropsy and histopathologic examinations of all organ systems did not reveal changes that could be attributed to radiation, although minute biologic injury at the molecular level could not be discounted.

5420 RESPONSE OF LYMPHOCYTES IN VITRO TO 30-MHZ RADIO-FREQUENCY FIELDS (MEETING ABSTRACT). *(Eng.)* Lovely, R. H.; Sparks, T. J.; Guy, A. W. *In: Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves.* Sponsored by The International Union of Radio Science & The U.S. Committee for URSI, held at Airlie, VA on October 30, 1977-November 4, 1977: pp. 138; 1977: pp. 138; 1977. (0 refs)

Mitogen-stimulated lymphocyte cultures were exposed to 30-MHz radio frequency fields and compared as to mitotic index and blast-cell percentage with non-exposed cultures. No significant differences were observed between exposed and nonexposed cultures. However, the number of successful cultures (cultures containing at least 10^6 cells with a significant percentage of transformations) was significantly lower in exposed cultures.

5421 DIFFERENTIAL EFFECTS OF RF RADIATION ON SUBPOPULATIONS OF MURINE LYMPHOCYTES (MEETING ABSTRACT). *(Eng.)* Liburdy, R. P. *In: Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves.* Sponsored by The International Union of Radio Science & The U.S. Committee for URSI, held at Airlie, VA on October 30, 1977-November 4, 1977: pp. 139; 1977. (0 refs)

The lymphocyte population in the spleen of mice that exhibited radio frequency (RF)-induced, acute lymphopenia was examined for altered heterogeneity with respect to expression of complement-binding and spontaneous sheep red blood cell (SRBC)-binding surface receptors. Mice that exhibited RF-induced lymphopenia showed a relative enrichment of complement-dependent, SRBC rosette-forming lymphocytes (CRL) and a depletion of spontaneous SRBC rosette-forming lymphocytes (SRL). The relative percentage of splenic CRL in RF-exposed mice was 1.5-fold

greater than that observed in sham-exposed mice (32.0 ± 3.1/20.8 ± 4.3, n = 12). The relative percentage of SRL in RF-exposed mice was 2.1-fold less than that in sham-exposed mice (13.1 ± 2.4/27.3 ± 5.1, n = 12). In contrast, RF-exposure to 26-MHz fields at reduced intensity (2.5 W/kg specific absorption rate [SAR]), which produced no lymphopenia, also produced no alterations in splenic populations of CRL and SRL. To investigate the effects of RF radiation on peripheral blood lymphocytes (PBL), splenectomized mice were exposed to 26-MHz radiation (26.7 W/kg SAR). The PBL were collected by cardiac puncture and isolated on a Ficoll-sodium metrizoate density gradient. The PBL population showed an increase in CRL and a decrease in SRL that was more marked than that observed in splenic lymphocytes from RF-induced lymphopenic mice. Lymphopenia accompanied by increased splenic CRL and decreased splenic SRL could be induced in quiescent mice by administration of methyl prednisolone sodium succinate. The data suggest that the differential effects of RF-radiation on mouse lymphocytes may be the result of an in vivo release of corticosteroids in response to thermal stress from RF radiation.

5422 CHRONIC EXPOSURE OF RATS TO 425- or 2450-MHZ MICROWAVE RADIATION EFFECTS ON LYMPHOCYTES (MEETING ABSTRACT). *(Eng.)* Smialowicz, R. J.; Kinn, J. B.; Weill, C. M.; Ward, T. R. *In: Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves.* Sponsored by The International Union of Radio Science & The U.S. Committee for URSI, held at Airlie, VA on October 30, 1977-November 4, 1977: pp. 140; 1977. (0 refs)

Rats were exposed in utero and through 40 days of age for 4 hr/day in a temperature-controlled environment to continuous wave (CW) microwaves either at 2,450-MHz in an anechoic chamber or at 425 MHz (CW) in a transverse electromagnetic mode (TEM) transmission line. The power densities of incident radiation were 5 mW/cm^2 at 2,450 MHz and 10 mW/cm^2 at 425 MHz. Specific absorption rates (SAR) for rats of different ages were determined by twin-well calorimetry at each frequency. At 2,450 MHz, SAR values from 1 to 5 mW/g were calculated for pregnant rats and for pups to 40 days of age. For rats exposed to 425 MHz, SAR values between 3 and 7 mW/g were also computed from measurements of forward, reflected, and transmitted power. Rats were sacrificed at 20 and 40 days of age, and blood was obtained for complete blood counts. In addition, the in vitro blastogenic response of blood and lymph node lymphocytes was measured by ^{3}H-thymidine incorporation into DNA following stimulation of the cells with T- or B-lymphocyte mitogens. Exposure of rats at 425 MHz resulted in an absolute neutropenia and a relative lymphocytosis in two of three experiments. Significant increases ($p<.05$) in the response of lymph node lymphocytes to stimulation with phytohemagglutinin (PHA) were observed in irradiated rats. Also, the response of lymph node lymphocytes to B-cell mitogens increased significantly. In animals exposed to 2,450 MHz there were changes in the mitogen response of both T- and B-lymphocytes from lymph nodes and T-lymphocytes from blood. However, there were no changes in peripheral blood counts after exposure at the higher frequency. The data indicate that chronic exposure of rats to microwaves at either 2,450 MHz or 425 MHz may result in changes in the mitogen-stimulated response of lymphocytes.

5423 ALTERATION OF CELL-MEDIATED IMMUNITY BY LOCAL MICROWAVE HYPERTHERMIA (43°C) OF GUERIN EPITHELIOMA (MEETING ABSTRACT). *(Eng.)* Szmigielski, S.; Janiak, M. *In: Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves.* Sponsored by The International Union of Radio Science & The U.S. Committee for URSI, held at Airlie, VA on October 30, 1977-November 4, 1977: pp. 141; 1977. (0 refs)

Tumor-bearing rats (Guerin's epithelioma) underwent three 1-hr sessions of localized microwave hyperthermia (LMwH) during wk 3 or 5 after tumor implantation. A rise of temperature in the tumor to 43±0.05 C was accomplished; electrical shielding helped maintain temperatures below 40 C in the remainder of the rat's body. Subsequently, in treatments prescribed by a factorial design, rats were infused with Streptolysin S (SLS) i.p., with *Corynebacterium parvum* (CP) intratumorally, with both agents, or with neither. Eight wk after implantation, the following results were noted: (1) LMwH in 12 rats during wk 3 resulted in three cures and eight tumor regressions; in contrast, treatment of 12 rats during wk 5 resulted in four regressions and no cures; and (2) LMwH, when combined with SLS or CP or both, was even more efficacious in eradicating tumors, especially when administered during wk 3. These data and those from immunologic assays indicate that LMwH is not only a selective killer of cancer cells but acts as a potent immunostimulator.

5424 FURTHER CHARACTERIZATION OF MICROWAVE-INDUCED CHANGES IN SUBPOPULATIONS OF LYMPHOID SPLEEN CELLS IN THE MOUSE WITH PARTICULAR REFERENCE TO COMPLEMENT-RECEPTOR-BEARING LYMPHOCYTES (MEETING ABSTRACT). *(Eng.)* Wiktor-Jedrzejczak, W.; Ahmed, A.; Leach, W. M.; Czerski, P.; Cyr, H.; Sell, K. W. *In: Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves.* Sponsored by The International Union of Radio Science & The U.S. Committee for URSI, held at Airlie, VA on October 30, 1977-November 4, 1977: pp. 142; 1977. (0 refs)

Exposure of the mouse to 2,450-MHz microwaves results in an increased number of complement-receptor-bearing lymphocytes (CRLs) in the spleen. Further characterization of this effect was investigated through single exposures of CBA/J mice in an environmentally controlled waveguide. An increase of CRLs was observed between day 4 and 10 after radiation, a plateau occurring after day 6. The increase was more pronounced when flow of radiation

proceeded from tail-to-head as opposed to head-to-tail; increased variability resulted when flow was incident on the mouse's saggital plane. The increase was dose dependent, the strongest response occurring to a dose of 40 J/g (45-min exposure); between 10 and 20 mW/g, the level of CRLs was independent of dose-rate. Amplitude modulation at 12 Hz yielded results that were similar to those obtained with continuous wave radiation. Assessment by a combined, immunofluorescent-rosetting technique revealed that the increased sub-populations were predominantly of CR^+ and Ig^+ B-cells. There was also an increase in Fc-receptor-bearing B-cells that was unrelated to changes of number either in theta-positive or in E-rosette-positive T-cells.

5425 THE RELATIONSHIP OF THERMAL STRESS TO IMMUNE-SYSTEM RESPONSE IN MICE EXPOSED TO 2.6-GHZ RADIO-FREQUENCY RADIATION (MEETING ABSTRACT). *(Eng.)* Krupp, J. H. *In: Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves.* Sponsored by The International Union of Radio Science & The U.S. Committee for URSI, held at Airlie, VA on October 30, 1977-November 4, 1977: pp. 143; 1977. (0 refs)

To investigate the relationship of thermal stress to immune-system response, hybrid inbred mice were exposed to 2.6-GHz radio frequency radiation at power densities of 10, 15, and 20 mW/cm^2 for different periods of time. Sensitization by innoculation with sheep red blood cells (SRBC) was done at various times before and after radiation. Four days after the sensitizing treatment, spleens were harvested and assayed for the presence of plaque-forming cells (PFC) in SRBC films. Increased numbers of PFC occurred whenever the exposure conditions were such as to produce a rise of rectal temperature by 3.0 C. The greatest increase occurred when sensitization followed radiation exposure by 4 hr, coinciding with the peak of a shift in peripheral lymphocyte/leucocyte ratio. Repeated exposures over a week or more did not increase PFC numbers so long as the specific absorption rate (SAR) of any fraction did not exceed that which produced the threshold temperature. The same response could be elicited by the administration of cortisone, which indicates that the observed changes were an adrenal-mediated response to thermal stress. Biologic response as a function of SAR is discussed.

5426 A 915-MHZ EXPOSURE SYSTEM FOR HYPERTHERMAL TREATMENT OF CANCER (MEETING ABSTRACT). *(Eng.)* Johnson, C. C.; Plenk, H.; Durney, C. H. *In: Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves.* Sponsored by The International Union of Radio Science & The U.S. Committee for URSI, held at Airlie, VA on October 30, 1977-November 4, 1977: pp. 149; 1977. (0 refs)

A 915-MHz microwave system for inducing hyperthermia is described. Energy is supplied by a microwave generator to a rectangular direct-contact diathermy applicator with matching through a double-stub tuner. Approximately 50 W are required to obtain a therapeutic elevation of temperature in deep tissues to the 42-43 C range. The applicator is 13 cm x 13 cm and is fitted with a plastic cover plate through which cool air is blown to control surface temperature. Surface cooling is essential to obtain an optimal temperature profile in the tissues. Experiments were performed on tissues of normal animals to gain experience with requirements for power with the applicator and with thermometry. Animals with spontaneous tumors were treated, and significant regression and necrosis were observed in several cases. The results of preliminary experiments are reported, and resulting design-specifications for a 915-MHz hyperthermia system for cancer treatment are outlined.

5427 EXPERIMENTAL AND NUMERICAL STUDIES OF TEMPERATURE IN A HUMAN LEG HEATED BY DIATHERMY (MEETING ABSTRACT). *(Eng.)* Emery, A. F.; Stonebridge, J.; Sekins, M. *In: Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves.* Sponsored by The International Union of Radio Science & The U.S. Committee for URSI, held at Airlie, VA on October 30, 1977-November 4, 1977: pp. 150; 1977. (0 refs)

A section of the human thigh was modeled by a finite-element thermal analyzer, and the transient elevations of temperature resulting from application of diathermy were computed. Computations were performed for normal application, application with a simultaneous cooling of the skin, and application after pre-cooling of the limb. The aim was to develop a treatment schedule that would yield the desired core temperature while not producing unacceptably high temperatures in other regions of the thigh. Temperatures were measured in subjects undergoing the treatments and were compared to the computations to verify the assumptions used in the computer-model. The results have enabled the establishment of guidelines necessary for efficient diathermy of tissues well below the surface of the thigh.

5428 A STUDY OF LEAKAGE FIELDS NEAR THERAPEUTIC 915- AND 2450-MHZ APPLICATORS AS APPLIED TO MODELS AND AS USED IN HUMAN EXPOSURES (MEETING ABSTRACT). *(Eng.)* Lehmann, J. F.; Guy, A. W.; Stonebridge, J. *In: Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves.* Sponsored by The International Union of Radio Science & The U.S. Committee for URSI, held at Airlie, VA on October 30, 1977-November 4, 1977: pp. 151; 1977. (0 refs)

An XYZ tracking system (controlled by a DDP-516 Honeywell computer) with a National Bureau of Standards EDM-1C high density probe was used to plot the radiation levels in an anechoic chamber. Stray radiation resulting from various contact and noncontact applicators was plotted using models

that were representative of the electrical properties of tissues and were shaped according to human anatomy. The system was calibrated initially by using microwave sources with known theoretic near- and far-zone fields at 915 MHz and 2,450 MHz. The most common types of therapeutic applications were duplicated. For further verification, the same plots were made during exposures of human beings, which were identical to those used in therapy but with low output power for safety. Results obtained with the various applicators in the different types of situations can serve as a guide to the physician who wishes to apply these modalities while avoiding exposure of sensitive organs such as eyes and testes. In addition, this evaluation provides valuable information as to the best technique of application and the most suitable approaches to applicator design.

5429 LOCALIZED EMBEDDING OF LABELLED MICROSPHERES BY MICROWAVE HEATING IN TISSUES OF HYPOTHERMIC DOGS (MEETING ABSTRACT). *(Eng.)* Popovic, V.; Popovic, P. *In: Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves.* Sponsored by The International Union of Radio Science & The U.S. Committee for URSI, held at Airlie, VA on October 30, 1977-November 4, 1977: pp. 152; 1977. (0 refs)

The hind leg of a dog was profoundly cooled while the gracilis muscle of the same leg was kept slightly hyperthermic (37-39 C) by microwave heating (differential hypothermia) to study the preferential embedding of radionuclides. For muscle rewarming, a microwave system was used (S-band: 2,450 MHz) that comprised a 100-W continuous wave magnetron with a coaxial dual-directional coupler to monitor incident and reflected power. The system used dielectrically loaded and tapered wave guides. Labelled microspheres were injected as a bolus into the left ventricle of the heart. The circulation measured by trapping of Technetium (^{99}Tc)-labeled carbonized microsphere in capillaries through the warmed muscle tissues was 5 to 12 times greater than that measured through the cold muscles of the same leg. When differential hypothermia was used to induce selective embedding of Yttrium-(^{90}Y)-loaded microspheres in the warm gracilis muscle of the cooled leg, pronounced damage (or even complete destruction) of hyperthermic muscle tissue was observed while leaving undamaged all other muscle tissue that was protected by cooling. It is suggested that differential hypothermia might be useful in the preferential embedding of medical radionuclides whenever a superselective catheterization of tumors or of other tissues is not possible.

5430 THE EFFECTS OF HYPERTHERMIA, MICROWAVE RADIATION, AND ASCORBIC ACID ON THE METABOLISM OF EHRLICH ASCITES CARCINOMA CELLS IN VITRO (MEETING ABSTRACT). *(Eng.)* Plontek, G. E.; Cain, C. A.; Milner, J. A. *In: Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves.* Sponsored by The International Union of Radio Science & The U.S. Committee for URSI, held at Airlie, VA on October 30, 1977-November 4, 1977: pp. 154; 1977. (0 refs)

Ehrlich ascites tumor cells (EATC) were simultaneously incubated in vitro at the same temperature (37.5 or 42.5 C) in either a microwave field (200 mW/cm^2) or in a water bath. The differences in release of $^{14}CO_2$ due to the metabolism of uniformly labeled glucose (U-^{14}C-Glucose) from the irradiated and nonirradiated EATC were not statistically significant at the 0.01 level at 37.5 and 42.5 C. The presence of 1 mM ascorbic acid in the incubation media markedly stimulated glucose metabolism in EATC. The differences in release of $^{14}CO_2$ due to the metabolism of U-^{14}C-Glucose with ascorbic acid versus no ascorbic acid in the incubation media were statistically significant ($p<0.01$) at 37.5 and 42.5 C in both irradiated and nonirradiated samples. However, the differences in glucose metabolism between irradiated and nonirradiated cells in the presence of ascorbic acid were not statistically significant at either temperature. A number of other labeled compounds were used to characterize further the effects produced by cellular heating and ascorbic acid on EATC metabolism. $^{14}CO_2$ release from 1-^{14}C-pyruvate and 1.5-^{14}C-citrate metabolism were released at specific points in the glycolytic pathway and the trichloroacetic acid cycle, respectively. The release of labeled CO_2 from these compounds was increased significantly in the presence of ascorbate. In addition, cells incubated in the presence of ascorbate had a large decrease in their lactate levels. It has been reported that ascorbate inhibits the enzyme, phosphodiesterase, which in turn inhibits the breakdown of cyclic adenosine monophosphate (AMP) to AMP. Although the mechanism is unclear, cyclic AMP has been shown to inhibit the growth of some tumors in vivo. Since changes in nucleotide levels may be related to tumor growth, future research will determine the effects of cellular heating and ascorbic acid on cyclic AMP and the other adenosine nucleotides AMP, adenosine diphosphate, and adenosine triphosphate.

5431 EFFECTS IN VIVO OF COMBINED MICROWAVE AND X-RAY TREATMENT ON A TRANSPLANTABLE MOUSE MAMMARY ADENOCARCINOMA (MEETING ABSTRACT). *(Eng.)* Clarke, B. J. *In: Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves.* Sponsored by The International Union of Radio Science & The U.S. Committee for URSI, held at Airlie, VA on October 30, 1977-November 4, 1977: pp. 155; 1977. (0 refs)

The effects of microwave- and x-radiation, alone and in combination, on the growth in vivo of mammary adenocarcinoma (BW 10232) of C57 black/6J mice were explored. After tumor transplantation, mice were exposed either to microwaves (91.898 ±0.508 mW/g dose rate) or to x-rays (1,000 R) or to both (84.805 ± 2.49 mW/g dose rate and 1,000 R) for 2 wk. Both the combined treatment and x-rays alone significantly reduced growth of the tumor as compared with the control treatment ($P<.01$). However,

the combined treatment was no more effective than x-rays alone in retarding growth. The difference between microwave and control treatments was not significant (P>.10). A positive correlation was observed between amount of microwave energy absorbed and tumor mass. Although there were large areas of necrosis in tumors from both microwave- and x-radiated animals, all tumors contained cells that were undergoing mitosis. The in vivo studies indicate that x-rays successfully inhibit tumor growth, while microwaves appear to stimulate tumor growth.

5432 COMBINED EFFECTS OF PULSED MAGNETIC RADIATION (DIAPULSE) AND CHEMOTHERAPY ON TUMOR-BEARING MICE (MEETING ABSTRACT). *(Eng.)* West, B.; Regelson, W. *In: Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves.* Sponsored by The International Union of Radio Science & The U.S. Committee for URSI, held at Airlie, VA on October 30, 1977-November 4, 1977: pp. 156; 1977. (0 refs)

The effect of simultaneous treatment utilizing pulsed radiowaves and cancer chemotherapy on the life spans of BDF_1 mice with Lewis lung carcinoma was investigated. In comparison to non-treated controls, the combination of hydroxyurea and whole-body non-ionizing electromagnetic irradiation (at 27.12 MHz) produced differential enhancement of longevity of 5 and 102%, depending on output power. The higher power (38 root mean square [rms] W) had the greatest effect. The lower power (5 rms W) and the hydroxyurea administered alone did not significantly alter the time-to-death. Hydroxyurea combined with the higher power output (38 mean W achieved by pulsing the radiation 600 times/sec; at a 3.9% duty cycle, peak W=975) produced a mean extension of life 67% greater than that of the group treated with hydroxyurea alone. A second drug, Cytoxan, when administered 500 hr after transplanting of tumor, consistently produced significant prolongation of life. A 28% extension of life over that from Cytoxan alone resulted from daily exposure at the lower power output (5 mean W, 160 pulses/sec at 490 peak W with a 1% duty cycle) throughout the course of the chemotherapy treatment. A third drug, bleomycin, did not alter life span either alone or in conjunction with non-ionizing irradiation. Further studies are underway with L1210 leukemia and with other anti-tumor agents to determine the consistency of the findings and whether they relate to drug metabolism, thermal effects, or the action of pulsed magnetic fields on the host.

5433 THE RESPONSE OF PIG SKIN TO COMBINED X-IRRADIATION AND MICROWAVE HEATING (MEETING ABSTRACT). *(Eng.)* Field, S. B.; Hand, J. W. *In: Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves.* Sponsored by The International Union of Radio Science & The U.S. Committee for URSI, held at Airlie, VA on October 30, 1977-November 4, 1977: pp. 157; 1977. (0 refs)

To study the response to combined x-irradiation and microwave heating, 2,450 MHz electromagnetic radiation was applied to pig skin via a surface applicator for 1.5 hr at 42 C. The temperature was measured by fine thermocouples, perpendicular to the electric field and was found to be uniform through pigs' dermis. A liquid crystal thermometer was later used as a check. In contrast to data previously obtained with rodents, there was little thermal enhancement on the pig skin. Whether this result is due to a difference between animal species or to different techniques of heating is discussed.

5434 DESTRUCTION OF SOLID TUMORS BY HEATING WITH RADIO-FREQUENCY ENERGY (MEETING ABSTRACT). *(Eng.)* Dickson, J. A. *In: Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves.* Sponsored by The International Union of Radio Science & The U.S. Committee for URSI, held at Airlie, VA on October 30, 1977-November 4, 1977: pp. 158; 1977. (0 refs)

A radio frequency (RF) generator that operates at 13.56 MHz was developed for use in cancer hyperthermia. The apparatus employs the condenser-field technique whereby the tissue is part of the output circuit and is heated between two paddle electrodes that are applied on opposite sides of the tumor. Tuned compensating coils in the handles of the paddles, a connector lead between the paddles, and an inverse direct current feedback loop between the RF output and the crystal oscillator produce stable and readily controlled heating of a tumor. One hundred and eight subcutaneous murine tumors of three different types at various sites and up to 3 cm^3 in volume were heated to 45 or 50 C for 15 to 30 min. A regression rate of 100% was seen. Twenty-five intramuscular VX2 tumors (10 to 25 cm^3) in rabbits were treated at 47 or 50 C for 15 to 30 min, with a 75% regression rate. There was no damage to normal tissues, and temperature of the skin over these tumors remained 4 to 6 C below that of the tumor during the heating.

5435 TREATMENT OF TUMORS WITH 69-CM DIATHERMY (MEETING ABSTRACT). *(Eng.)* Ollendiek, H. *In: Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves.* Sponsored by The International Union of Radio Science & The U.S. Committee for URSI, held at Airlie, VA on October 30, 1977-November 4, 1977: pp. 159; 1977. (0 refs)

Patients with advanced metastatic carcinoma were treated with an infusion of thymus extract combined with whole-body hyperthermia (~41 C) as induced by focally applied 69-cm radiation. The treatments were administered twice a week, and over a period of 4 wk, the duration of hyperthermia was increased from 90 min to 5 hr. Remissions occurred in several patients. In some cases, tumors distal to the site of application of 69-cm radiation regressed. It is concluded that the most important clinical effect of hyperthermia is the immunologic unmasking of the

tumor cell. Heating of the body appears to facilitate recognition of the tumor cell membrane as an antigen, thereby provoking the production of antibodies. In light of this, the authors propose a new course of cancer therapy in which antibodies from animals previously implanted with homogenates of human tumors would be extracted, separated, and injected into the cancer patient, who would then undergo whole-body hyperthermia.

5436 TECHNIQUES AND RESULTS OF USING MICROWAVES AND X-RAYS FOR THE TREATMENT OF TUMORS IN MAN (MEETING ABSTRACT). *(Eng.)* Joines, W. T.; Noell, T. K.; Miller, L. S.; Woodward, K. T. *In: Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves.* Sponsored by The International Union of Radio Science & The U.S. Committee for URSI, held at Airlie, VA on October 30, 1977-November 4, 1977: pp. 160; 1977. (0 refs)

X-rays and microwaves, alone and in combination, were used to treat six terminal cancer patients. X-rays and microwaves were administered every second day for a total of four treatments. In most cases, the combined treatment led to a total regression of the tumor within ~4.5 wk of the initial treatment. The same microwave heating (43.5 C for 30 min) and x-ray dose (400 rads), when applied separately to other tumors of the same patient, caused a 40% regression of the tumor in about 4.5 wk. Theoretic and experimental data relating to selective heating and depth of penetration in tumors by microwaves indicate that the optimal microwave frequencies for heating cancerous tissue lie in a range that approximates 0.5 to 1 GHz. By using a variable-aperture contact applicator a complete system for automatically controlled microwave heating of cancerous tissue was developed. Heating could be produced for any length of time at a selected location within an accuracy of ± 0.1 C. The temperature was monitored by tissue-implantable thermistor probes that were oriented at right angles to the microwave electric field; sample readings of temperature were made only during 1 msec periods (that occurred every 100 msec) when radiation was not applied. The direct-contact applicator was a double-ridge waveguide horn-antenna that operated in the 0.9- to 4-GHz range. By placing aluminum adhesive tape directly on the surface between the tissue and the horn antenna but leaving an opening that defined the area to be irradiated, the aperture could be adjusted from about 8 by 12 cm to the 17 by 22.75 cm opening of the horn antenna, while maintaining a fairly uniform pattern of heating across the aperture.

5437 EFFECTS OF 434-MHZ ELECTROMAGNETIC WAVES ON HUMAN CANCERS (MEETING ABSTRACT). *(Eng.)* Holt, J. A. G. *In: Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves.* Sponsored by The International Union of Radio Science & The U.S. Committee for URSI, held at Airlie, VA on October 30, 1977. November 4, 1977: pp. 161; 1977. (0 refs)

The effects of whole- or part-body microwave radiation (434 MHz) on the progress of malignant tumors in 380 cancer patients irradiated in the near field were studied. At power levels exceeding 35 mW/cm^2, the only demonstrable effects were on hemoglobin and male fertility. Changes in pulse rate, blood pressure, and electrolytes occurred proportionately to the degree of whole-body hyperthermia that was induced by radiation and were similar to changes from hyperthermia induced by conventional methods. Microwave radiation had destructive effects on certain bacterial colonies and altered the normal bowel flora. Normal repair processes were not impeded, and no effect on blood clotting and coagulation was observed.

5438 PULSED ELECTROMAGNETIC ENERGY IN THE ENHANCEMENT OF BODILY REPARATIVE PROCESSES (MEETING ABSTRACT). *(Eng.)* Photiades, D. P.; Osamo, N. O. *In: Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves.* Sponsored by The International Union of Radio Science & The U.S. Committee for URSI, held at Airlie, VA on October 30, 1977-November 4, 1977: pp. 162; 1977. (0 refs)

Pulsed electromagnetic waves in the 14-MHz band have been used successfully to potentiate resolution of hematoma and to accelerate healing of wounds experimentally. Clinically, successful short-term remissions were achieved in eight cases of chronic leukemia with energy in the 27-MHz band (Diapulse) without recourse to specific drug therapy.

5439 STUDIES OF BLOOD-BRAIN BARRIER PERMEABILITY AFTER MICROWAVE RADIATION (MEETING ABSTRACT). *(Eng.)* Merritt, J. H. *In: Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves.* Sponsored by The International Union of Radio Science & The U.S. Committee for URSI, held at Airlie, VA on October 30, 1977-November 4, 1977: pp. 164; 1977. (0 refs)

Since reported alterations of permeability of the blood-brain barrier (BBB) by radiofrequency radiation have implications for the safety of man, studies were conducted to replicate some of the investigations. Increased BBB permeation by fluorescein in the rat as a result of microwave irradiation at low power densities (2 mW/cm^2 continuous wave or 0.2 mW/cm^2 root mean square (rms) for pulsed radiations) has been demonstrated. Alterations in the uptake of ^{14}C-labeled saccharides of small molecular weight across the BBB of rats also have been reported. An attempt to replicate the fluorescein study was not successful. The study was extended to include chemical assay of fluorescein in the rat's brain after animals were radiated by pulsed 1.2-GHz microwaves at power densities to 38 mW/cm^2 rms. Compared with controls, there was no significant increase in fluorescein in any area of the brain. Animals were also heated in a warm-air

oven or by microwave radiation to achieve a change of brain temperature of 4 C. Under these conditions an increase in permeation of the blood-brain barrier by fluorescein was observed. A study on brain uptake of ^{14}C-labeled saccharides at the previously reported parameters of microwave irradiation also failed to confirm the original finding of increased permeability. The data gathered from three separate experiments on rats that were radiated at 1.2 GHz indicate that hyperthermia of the brain is necessary for inducing permeation of blood-brain barrier by large or small molecules. The results are discussed in the context of safety standards for nonionizing electromagnetic radiation

5440 EFFECTS OF MICROWAVE-INDUCED HYPERTHERMIA ON THE RAT BLOOD-BRAIN BARRIER (MEETING ABSTRACT). *(Eng.)* Sutton, C. H. *In: Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves.* Sponsored by The International Union of Radio Science & The U.S. Committee for URSI, held at Airlie, VA on October 30, 1977-November 4, 1977: pp. 165; 1977. (0 refs)

The effects of microwave radiation at 2,450 MHz on the blood-brain barrier were investigated in rats. Horseradish peroxidase, a basic enzymatic protein, was used as a tracer and was injected intravenously before heating of the brain by microwaves. After heating, rats were sacrificed by aortal perfusion with iso-osmotic saline at a temperature of 4 C. Homogenates of brain were then assayed for residual peroxidase activity, which was used as an indicant of disruption of the blood-brain barrier. Heads of rats were heated by microwave radiation to 37, 40, 42, or 45 C for periods of 10, 15, or 30 min, while the animals' bodies were shielded with Eccosorb microwave-absorbing material. After 10 min, there was residual peroxidase activity in brain at 45 C, indicating disruption of the barrier. There was similar disruption after heating to 42 C for 15 min. To preserve the integrity of the blood-brain barrier and to permit the brain to be heated safely for longer periods, the brain's tolerance to microwave radiation was compared to normothermic (37 C) and to hypothermic (30 C) rats. In addition to an increase of survival time, body-core hypothermia protected integrity of the barrier for 15 and for 30 min at 45 and 42 C, respectively. When brain temperature was maintained at 40 C, the protective effect of body-core hypothermia was most pronounced. Barrier integrity was lost after 45 and 60 min of irradiation in normothermic rats but remained intact for 2 to 3 hr in hypothermic animals. It is concluded that microwave radiation is capable of disrupting the blood-brain barrier. The brain's tolerance to microwave is dose-related, depending both upon the elevation of temperature and upon duration of elevation.

5441 REVERSIBILITY OF THE BLOOD-BRAIN BARRIER (MEETING ABSTRACT). *(Eng.)* Albert, E. N. *In: Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves.* Sponsored by The International Union of Radio Science & The U.S. Committee for URSI, held at Airlie, VA on October 30, 1977-November 4, 1977: pp. 166; 1977. (0 refs)

The reversibility of microwave-induced changes in the permeability of the blood-brain barrier was investigated in Chinese hamsters irradiated with 2,450-MHz microwaves at a power density of 10 mW/cm^2. Appropriate sham-irradiated controls were used for comparison. After irradiation treatment, all animals were allowed to recover for periods to 2 hr and then were injected with 10 mg of horseradish peroxidase via the femoral vein. Two to 5 min after injection the animals were perfused with glutaraldehyde and then were dissected, sliced, and treated with 3-3' diaminobenzidine. Gross and microscopic examination of incubated sections revealed that after 1 hr of recovery there was a decrease in the permeability of the blood-brain barrier as compared with sections from animals sacrificed immediately after irradiation. However, there was little leakage of peroxidase in brains of animals that were sacrificed after a 2-hr period of recovery. These observations indicate that a partial restoration of the blood-brain barrier's impermeability may have occurred within an hour of irradiation and virtually complete restoration within 2 hr. These conclusions are limited to passage of molecules of the size and properties of horseradish peroxidase (molecular weight 40,000), e.g., proteins, such as, serum albumins.

5442 DETERMINANTS OF BRAIN UPTAKE (MEETING ABSTRACT). *(Eng.)* Oscar, K. J. *In: Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves.* Sponsored by The International Union of Radio Science & The U.S. Committee for URSI, held at Airlie, VA on October 30, 1977-November 4, 1977: pp. 167; 1977. (0 refs)

The implications of microwave-induced central nervous system alterations and the extent to which changes of permeability may explain recently reported effects of microwave irradiation at low power densities are discussed. The blood-brain exchange of proteins, electrolytes, and large water-soluble non-electrolytes is restricted due to a continuous layer of cerebro-vascular endothelial cells that are characterized by tight junctions and a scarcity of pinocytotic vesicles for transport. Microwave-induced changes in brain distribution and uptake of blood-carried substances have been reported in work performed on rats, Chinese hamsters, and rabbits. Horseradish peroxidase, sodium fluorescein, radiolabeled saccharides of varying molecular weights, and labeled dibasic phosphate salt have all exhibited increases in blood-brain exchange. There are indications that these alterations are reversible, which may indicate changes in tight-junction integrity or pinocytotic transport rather than cell-membrane destruction. The blood-brain barrier (BBB) has been similarly opened reversibly by treatments involving convulsions, cerebral concussions, hypercapnia, acute hyper-

tension, ionizing radiation, and infusion with hypertonic solutions. Many of these conditions alter the autoregulation of blood flow, which may cause widening of tight junctions by endothelial-cell shrinkage or capillary dilatation. Investigators of effects of microwave irradiation on brain uptake have used several different techniques of measurement and observation including optical-, ultraviolet-, and electron-microscopy, chemical assay, single-radioisotopes, and double radio-labeled indicators with highly diffusible reference substances as a ratio standard. Most of these techniques measure the net influence of several variables on brain uptake; these techniques do not differentiate the effects of changes in the vascular space, alterations of blood flow, and changes of BBB permeability. These BBB investigative techniques as well as others (e.g., dual compartment analysis) are discussed with emphasis on how each may affect interpretation of results.

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This quarterly digest presents current awareness information on the biological effects of nonionizing electromagnetic radiation (microwave and radiofrequency) in the range of 0 Hz to 100 GHz. The effects of magnetic and electric fields (static and alternating) are also covered. Each issue contains abstracts of English and foreign current literature, summaries of ongoing research investigations, news items, and a directory of meeting and conferences.

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