day, from 0 to 11 inclusive, to determine on which day(s) the mice were most radiosensitive with respect to the microwave induction of fetal deaths and anomalies. It was found that day 8 showed a significant increment in fetal deaths and anomalies (controls 22.3% and 8 days 68.0%). The most frequent effects were resorptions and deaths, occurring shortly after irradiation. With counts of congenital anomalies only, days 4 and 8 appeared to show percentage increments but below significant levels for the number of animals; only 10% showed exencephalia (brain hernia) compared with less than 1% for controls. Examinations were made at 18 gestation days. The results agree with those previously shown for effects of ionizing radiations, suggesting that day 8 is the most radiosensitive day for the mouse embryo and fetus. (No refs.)

5013 RESPONSE OF SWINE TO 60 Hz ELECTRIC FIELDS (MEETING ABSTRACT). (Eng.) Hjeresen, D. L.; Beamer, J. L.; Kaune, W. T.; Phillips, R. D.; Richardson, R. L. *In: Proceedings of the 1976 Annual Meeting of the International Union of Radio Science Held at the University of Massachusetts, Amherst, Massachusetts, 11-15 October, 1976.* USNC/URSI. (Washington, D.C.): 146; 1976.

Experiments were conducted to determine whether Hanford Miniature Swine (HMS) could be exposed to large electric fields without acute side effects and to determine the upper limit on field strength, up to 55 kV/m, that would not produce corona (ozone) on or near the animal, shocks from a drinking watering system, or visible hair stimulation. Four HMS were trained to drink from a watering system in response to a 750 Hz tone. Observations were made to detect any changes in drinking behavior as a function of electric field strength. The drinking response and general behavior of swine appeared normal at field strengths up to 50 kV/m. No corona occurred on or near the swine at field strengths up to 55 kV/m. Animals standing on a grounded metal plate did not receive shocks from the grounded watering system at field strengths as high as 55 kV/m; swine insulated from ground received shocks at 10 kV/m. The threshold field strength for piloerection and hair oscillation was about 50 kV/m. Experimental evidence was obtained that indicated HMS perceive electric fields at 30 to 40 kV/m. (No refs.)

5014 INTERACTION OF SWINE WITH 60 Hz ELECTRIC FIELDS (MEETING ABSTRACT). (Eng.) Kaune, W. T.; Beamer, J. L.; Hjeresen, D. L.; Phillips, R. D.; Richardson, R. L. *In: Proceedings of the 1976 Annual Meeting of the International Union of Radio Science Held at the University of Massachusetts, Amherst, Massachusetts, 11-15 October, 1976.* USNC/URSI. (Washington, D.C.): 145-146; 1976.

The interaction of Hanford Miniature Swine with uniform, vertical, single-phase, 60 Hz electric fields was investigated. Four swine were individually tested during exposure to electric fields (to 55 kV/m), while housed in a Plexiglas pen with a grounded metal floor. The electrical resistance between the ground plane and the swine was about 2,000 ohms. The current between the swine's mouth and the grounded watering fixture was a linear function of field strength and in no case exceeded 165 μAmp at a field strength of 55 kV/m. The threshold for perception of a mouth to watering system current was measured in another experiment and was found to be greater than 225 μAmp for all swine. At 20 kV/m, the average short circuit current of four swine was 135 ± 11 μAmp. The electric field was markedly distorted by the swine's body and was increased by a factor of 6.7 at the top of the back. Calculations based on an ellipsoidal model of swine predicted a value of 6.6 for this enhancement factor and a short circuit current of 125 μAmp at a field strength of 20 kV/m. (No refs.)

5015 CHRONIC EXPOSURE OF PRIMATES TO ELECTRIC AND MAGNETIC FIELDS ASSOCIATED WITH ELF COMMUNICATIONS SYSTEMS (MEETING ABSTRACT). (Eng.) Grissett, J. D. *In: Proceedings of the 1976 Annual Meeting of the International Union of Radio Science Held at the University of Massachusetts, Amherst, Massachusetts, 11-15 October, 1976.* USNC/URSI. (Washington, D.C.): 145; 1976.

To assess the effects of chronic exposure to electric and magnetic fields associated with extra low frequency (ELF) communications systems, a group of 30 experimental animals *(Macaca mulatta)* and 30 control animals, pair-matched by age, sex, weight, and medical history were exposed continuously (experimental animals only) to magnetic and electric fields. The fields were similar to those experienced by man in contact with the soil surface directly above a buried ELF antenna. Blood samples were drawn weekly for biochemical analysis. Physical examinations were given at 6-wk intervals. Clinical and blood chemistry results for 294 days of exposure are presented. (No refs.)

5016 60-Hz ELECTRIC FIELD EXPOSURE SYSTEM FOR A MINIATURE SWINE COLONY (MEETING ABSTRACT). (Eng.) Gillis, J. L.; Beamer, R. L.; Richardson, R. L.; Allen, C. H.; Kaune, W. T. *In: Proceedings of the 1976 Annual Meeting of the International Union of Radio Science Held at the University of Massachusetts, Amherst, Massachusetts, 11-15 October, 1976.* USNC/URSI. (Washington, D.C.): 145; 1976.

A facility under construction is described that will permit the long-term study of electric field effects on miniature swine under well-defined conditions. It consists of a conducting-floor ground pad, nonconducting contiguous stalls, nonconducting roof and walls, and an overhead linear array of four tubular conductors connected to a high-voltage transformer. The design is intended to satisfy several criteria, including the following: (1) the voltage supply and electrode system must provide uniform, vertical 60-Hz electric fields of large magnitude; (2) the structures between the pad floor and electrode must not significantly perturb the applied field nor contri-

bute to ozone production; (3) the facility must provide for animal comfort and routine husbandry throughout the year; (4) the animals will be individually stalled to minimize mutual shielding and permit farrowing in the field; (5) remote monitoring of ambient conditions and observations of the colony, while the field is on, will be afforded by appropriate instrumentation; (6) zero-field facility, otherwise identical to the experimental colony facility, will be provided for control animals; and (7) the design should allow expansion for future animal generations with minimal expense and field interruption. (No refs.)

5017 THE EFFECT OF REPEATED MICROWAVE EXPOSURE IN NEONATAL RATS (MEETING ABSTRACT). (Eng.) Guillet, R.; Michaelson, S. *In: Proceedings of the 1976 Annual Meeting of the International Union of Radio Science Held at the University of Massachusetts, Amherst, Massachusetts, 11-15 October, 1976.* USNC/URSI. (Washington, D.C.): 144; 1976.

The effect of repeated microwave exposure was studied in neonatal rats (Long Evans Hooded) exposed to 40 mW/cm^2, 2,450 MHz, continuous wave (CW) radiation for 5 min each day from day 1 to day 6 of life. On postnatal day 7, the rats were either sacrificed, exposed to 2,450 MHz CW for a seventh time, or injected with adrenocorticotropic hormone (ACTH). Twenty min after the final exposure or injection, the animals were sacrificed. Trunk blood and adrenal glands were saved. No difference was found in plasma corticosterone concentrations between the rats previously exposed to microwaves and control animals that were not exposed. Basal plasma corticosterone concentrations were less than 2 µg% in both groups. Following either microwave exposure or ACTH injection on day 7, plasma corticosterone levels remained low (<3 µg%) in both exposed and control animals. A statistically significant increase in adrenal net weight was noted in animals exposed to microwaves on the first 6 postnatal days. The cause and biologic significance of this enlargement is unknown. It is hypothesized that because the first 2-3 wk after birth are very critical in the development of the rat, effects of microwave exposure during this period may be manifested at this time or at a later stage of life. (No refs.)

5018 INSECT PUPAE TERATOGENESIS IN A STANDING WAVE IRRADIATION SYSTEM (MEETING ABSTRACT). (Eng.) Olsen, R. G. *In: Proceedings of the 1976 Annual Meeting of the International Union of Radio Science Held at the University of Massachusetts, Amherst, Massachusetts, 11-15 October, 1976.* USNC/URSI. (Washington, D.C.): 144; 1976.

Teratogenesis was studied in pupae of the mealworm beetle, *Tenebrio molitar*, irradiated in the standing wave region of a continuous wave 4 GHz signal so that some of the pupae were positioned in an E-field maximum plane, while others were positioned in an adjacent H-field maximum plane. The standing wave pattern was produced by reflecting a plane wave at normal incidence from a metal plate suspended in the far field region of a horn-irradiated anechoic chamber. The physical cross section of the irradiated pupae accounted for less than 1% of the reflecting plate area to insure a minimum field perturbation, and the long axis of each pupa was oriented parallel to the H-field vector. For the reflected plane wave system in which the microwave dose rate was calorimetrically determined to be less than 12 mW/g in phantom insects, initial results showed teratogenic effects of irradiation in pupae positioned in both the E-field maximum plane and the H-field maximum plane; furthermore, the teratologic damage appeared to occur as often in either position. This result indicates that for this frequency and orientation, each field quantity can independently produce effects similar to those previously seen at X-band in waveguide irradiation systems. (No refs.)

5019 SUPPRESSION BY HYPERTHERMIA OR BY 2450 MHz MICROWAVES OF REPAIR OF DAMAGE PRODUCED BY IONIZING RADIATION (MEETING ABSTRACT). (Eng.) Lai, P. K.; Cain, C. A.; Ducoff, H. S. *In: Proceedings of the 1976 Annual Meeting of the International Union of Radio Science Held at the University of Massachusetts, Amherst, Massachusetts, 11-15 October, 1976.* USNC/URSI. (Washington, D.C.): 142; 1976.

It has been demonstrated that the lethal effect of gamma-radiation in normal or neoplastic mammalian cells is greatly reduced when a given dose is administered in two or more fractions separated by intervals of a few hours. This sparing effect of dose fractionation (Sdf) implies repair of some of the damage during the interval between fractions; Sdf is abolished, if the irradiated cells are subjected to hyperthermia (41°-43°C) between fractions. In this investigation, the suppression by hyperthermia, or by microwaves, of repair of damage produced by ionizing radiation was studied in intact flower beetles. Hyperthermia (43°-45°C) applied for 2 hr after the first fraction not only abolished Sdf during the 2-hr interval but caused protracted suppression of Sdf. Suppression of Sdf was observed even when it was found that the treated beetles were returned to the normal incubation temperature of 30°C for several hours before the second gamma-radiation exposure. Similar suppression of Sdf was obtained by 2-hr exposure to 2,450 MHz radiation after the first gamma-irradiation. These results suggest the feasibility of using microwaves to produce localized hyperthermia in tumors, while permitting normal tissues to repair damage during fractionated radiotherapy. (No refs.)

5020 MICROWAVE HYPERTHERMIA AND Co-60 RADIATION TREATMENT OF HAMSTER MELANOMA (MEETING ABSTRACT). (Eng.) Vetter, R. J.; Stoetzel, G. A.; Shupe, R. *In: Proceedings of the 1976 Annual Meeting of the International Union of Radio Science Held at the University of Massachusetts, Amherst, Massachusetts, 11-15 October, 1976.* USNC/URSI. (Washington, D.C.): 140; 1976.

The effect of microwave hyperthermia, alone and in combination with ^{60}Co radiation, and infrared hyperthermia alone, on an amelanotic melanoma specific to golden Syrian hamsters was investigated. In preliminary work, treatments with 250 kV x-rays as high as 800 rads per treatment given on 5 consecutive days had no effect on melanoma growth, confirming radioresistance reported in the literature. In this study, duration of hyperthermia was 12 min and ^{60}Co exposure was 200 R per treatment. Experimental groups were divided into high and low tumor temperature subgroups (46.0°C and 41.5°C for infrared). Tissue temperature was difficult to control in the microwave groups resulting in wide variation in tumor temperatures. Tumor volumes and survival times were recorded to judge treatment efficacy. Tumor regression and mean survival time in the high-temperature microwave plus ^{60}Co group were significantly greater than in all other treatment groups. It is suggested that high temperature microwave hyperthermia increases radiosensitivity and should be considered as a potential adjunct to cancer radiotherapy. (No refs.)

5021 ASCORBIC ACID LEVELS IN RABBIT EYES AFTER SINGLE AND REPEATED EXPOSURE TO MICROWAVE RADIATION (MEETING ABSTRACT). (Eng.) Ferri, E. S. *In: Proceedings of the 1976 Annual Meeting of the International Union of Radio Science Held at the University of Massachusetts, Amherst, Massachusetts, 11-15 October, 1976.* USNC/URSI. (Washington, D.C.): 118-119; 1976.

It has been shown that an early response to the induction of microwave cataracts in rabbits has been a change in the ascorbic acid content of the lens. Whether this reduction continues to occur beyond that reported and whether repetitive subthreshold exposures will evoke a similar response was investigated. The right eyes of New Zealand white rabbits were exposed 2 inches from the crossover of a direct current antenna to a power density of 500 mW/cm^2 for 8 min. Cataract formation resulted after a latent period of 3-7 days. At various intervals after exposure (5 min, 1/2 hr, 12 hr, 18 hr, 1 wk, 2 wk, and 4 wk) both the right and left eyes were removed, and ascorbic acid was assayed in the aqueous, vitreous, and lens. The eyes of unirradiated control animals were assayed following the same procedure. The aqueous humor showed an immediate decrease in ascorbic acid levels in irradiated eyes, continuing up to 1 wk postirradiation. At 2 wk, values were normal. Ascorbic acid levels in the lens decreased at a slower rate and did not reach the low levels in the aqueous but again rebounded at 2 wk to normal values. Erratic results were obtained for the vitreous humor. All values for unirradiated eyes, including controls and left eyes of animals, showed normal levels. Ascorbic acid was also assayed in irradiated eyes of rabbits exposed to repetitive short durations of microwave radiation. The animals were sacrificed, and the lenses assayed 1 wk postirradiation because ascorbic acid levels are at their lowest value at that time in the eyes of acutely exposed animals. No lowering of ascorbic acid levels in the eyes of these animals was observed. The results suggest that chronic subthreshold exposures totaling over three times in duration those of an acute nature do not provoke a reaction that affects ascorbic acid levels in the eye. (No refs.)

5022 DOSE RATE RELATED EFFECTS ON THE OXYGEN CONSUMPTION OF MICE DURING AND AFTER MICROWAVE IRRADIATION (MEETING ABSTRACT). (Eng.) Ho, H. S.; Edwards, W. P. *In: Proceedings of the 1976 Annual Meeting of the International Union of Radio Science Held at the University of Massachusetts, Amherst, Massachusetts, 11-15 October, 1976.* USNC/URSI. (Washington, D.C.): 119; 1976.

To investigate the thermal stress due to microwave radiation, the oxygen consumption rate was used as a biologic indicator in male CFI mice irradiated singly with 2,450 MHz continuous wave microwaves. Irradiation was performed in a waveguide apparatus with incident power levels of 0 (sham), 0.09, 0.3, 0.6, 1.7, and 3.3 W, resulting in corresponding average absorbed dose rates of 0 (sham), 1.5, 5, 10, 25, and 45 mW/g. The environmental conditions were 24°C, 60% relative humidity, and air flow rate of 76 ml/min. The rate of oxygen consumption of the mouse was determined at 5 min intervals by means of a paramagnetic oxygen analyzer before, during, and after each irradiation. Each of the stages lasted 30 min. Results of the experiment indicated reduction of oxygen consumption in addition to the previously reported avoidance behavior at average absorbed dose rates of 25 and 45 mW/g. Significant oxygen consumption reduction was also observed at 5 and 10 mW/g, even though avoidance was not observed at these average absorbed dose rates and environmental temperature. It is concluded that the animal homeostatic mechanism balances the total heat load to the organism by reducing its total metabolic heat rate to compensate for small heat load increases due to microwave radiation. (No refs.)

5023 EFFECT OF 3 GHz MICROWAVES ON EXPERIMENTAL VIRAL INFECTIONS IN MICE (HERPES, VACCINIA) (MEETING ABSTRACT). (Eng.) Szmigielski, S.; Luczak, M.; Janiak, M.; Kobus, M.; Laskowska, B. *In: Proceedings of the 1976 Annual Meeting of the International Union of Radio Science Held at the University of Massachusetts, Amherst, Massachusetts, 11-15 October, 1976.* USNC/URSI. (Washington, D.C.): 117; 1976.

To study the effect of microwaves on experimental viral infections, a series of experiments was performed in mice infected with viruses (Herpes or Vaccinia) under controlled conditions and irradiated with 3 GHz microwaves (anechoic chamber, far field conditions, 40 mW/cm^2, 2 hr daily). Irradiation was performed during different periods (2-14 days) before and/or after infection with viruses. Irradiation before viral infection did not change the course of disease, as measured by number of typical lesions on tail (vaccinia) or survival rate and occurrence of encephalitis (herpes). Irradiation after viral infection resulted in strong inhibition of replica-

tion of infective virus particles and lowering of number of typical lesions on tail (vaccinia). In mice infected with herpes viruses, survival in groups irradiated with microwaves was higher compared with controls; the occurrence of encephalitis was significantly lower. The best results were obtained in animals irradiated during the first 3 days after infection (period of varemia); irradiation during later phases of the disease was less effective. (No refs.)

5024 ENHANCED CYTOTOXIC EFFECT OF 3 GHz MICROWAVES FOR CELLS TREATED WITH MEMBRANE-INJURING SUBSTANCES (MEETING ABSTRACT). (Eng.) Szmigielski, S.; Janiak, M.; Kobus, M. *In: Proceedings of the 1976 Annual Meeting of the International Union of Radio Science Held at the University of Massachusetts, Amherst, Massachusetts, 11-15 October, 1976.* USNC/URSI. (Washington, D.C.): 116; 1976.

To investigate the enhanced cytotoxic effect of microwaves on cells treated with membrane-injuring substances, cells were treated with subcytotoxic (not resulting in detectable increase of number of dead cells stained with supravital dyes) concentrations of highly purified enzymes that injure cell membranes—bacterial phospholipases (staphylococcal sphingomyelinase and phosopholipase C from *Clostridium perfringens*). Digitonine in concentration 10^{-6} M was used as control membrane-injuring substance (inhibition of sodium pump and Na-K-activated ATPase). The experiments were performed on established cell cultures (WISH and FL lines) in the stationary phase of growth (48 hr after passage). Control cells and cells treated with the membrane-injuring substances were irradiated with 3 GHz microwaves (anechoic chamber, far field conditions, single session of irradiation lasting 1 hr) at nonthermal (5 mW/cm^2), subthermal (20 mW/cm^2), or thermal (40 mW/cm^2) field power densities. Viability of the cells, their morphology, as well as incorporation rate of ^{3}H-thymidine, ^{3}H-uridine, and ^{3}H-glycine and intracellular level of cyclic adenosine monophosphate were observed. It was found that treatment of cell cultures with subcytotoxic concentrations of the membrane-injuring enzymes and digitonine markedly enhanced the metabolic inhibitory effect of microwaves at subthermal and thermal power densities. (No refs.)

5025 EFFECTS OF 960 MHz MICROWAVE ON ISOLATED GUT SEGMENTS (MEETING ABSTRACT). (Eng.) McArthur, G. R.; Lords, J. L.; Durney, C. H. *In: Proceedings of the 1976 Annual Meeting of the International Union of Radio Science Held at the University of Massachusetts, Amherst, Massachusetts, 11-15 October, 1976.* USNC/URSI. (Washington, D.C.): 115; 1976.

Low level continuous wave, 960 MHz radiation of isolated segments of rat gut causes an increase in the activity of the gut preparation. A strain gauge pressure transducer was used to monitor the wave forms in a cannulated section of rat gut comprising the pyloric region of the stomach and the first 6 to 8 cm of the intestine. The preparation was suspended in isothermal, aerated, modified Ringer's solution. Microwave radiation was applied with a parallel peak capacitor type irradiator. The dose rate was calculated from temperature measurements made with the liquid crystal optical fiber temperature probe. It has been shown that similar radiation applied to isolated turtle and rat hearts causes bradycardia. These effects are thought to be neurally mediated by the release of transmitter substances from the autonomic nervous system. Generally these effects can be modified by the addition of drugs effective at synapses within the autonomic nervous system. In the heart, sympathetic and parasympathetic effects can be separated by the application of drugs, which selectively block these two divisions of the autonomic nervous system. Experiments to determine if similar drug treatment can be used to identify neural effects in the gut are in progress. (No refs.)

5026 EFFECTS OF RADIOFREQUENCY RADIATION ON PERIPHERAL VASCULAR PERMEABILITY (MEETING ABSTRACT). (Eng.) Liburdy, R. P. *In: Proceedings of the 1976 Annual Meeting of the International Union of Radio Science Held at the University of Massachusetts, Amherst, Massachusetts, 11-15 October, 1976.* USNC/URSI. (Washington, D.C.): 117; 1976.

The effects of radiofrequency radiation on absorption of sheep red blood cells (SRBC) in unsensitized Sprague-Dawley rats were investigated. Radiofrequency radiation (26 MHz, 2000 mW/cm^2, causing a 1.5°C increase in rectal temperature) was administered for 10 min on six successive days to three groups of ten test animals. On day six, 4 hr postexposure, SRBC at 10^8 cells in 50 µl were injected subcutaneously into the hind footpad of each animal. Breadth of the footpad was determined by micrometer before injection and 4 hr postinjection. Radiofrequency treated animals showed decreased footpad enlargement of 47.5% ($0.05<p<0.1$) and 36.8% ($0.05<p<0.1$) over that observed in sham exposed or warm air stressed animals, respectively. Microscopic histoexamination indicated that SRBC evoked a mild localized inflammatory reaction in all animals. These results suggest that radiofrequency radiation may be associated with increased vascular permeability over that due to frank thermogenic stress. (No refs.)

5027 FREE WATER AND THE MICROWAVE CONDUCTIVITY OF TISSUE (MEETING ABSTRACT). (Eng.) Schwan, H. P.; Foster, K. R. *In: Proceedings of the 1976 Annual Meeting of the International Union of Radio Science Held at the University of Massachusetts, Amherst, Massachusetts, 11-15 October, 1976.* USNC/URSI. (Washington, D.C.): 115; 1976.

Precision dielectric measurements on muscle tissue at frequencies of 0.1 and 10 GHz are reviewed. Over this frequency range, the tissue conductivity can be adequately represented by the sum of a Debye relaxation function and a constant term accounting for the electrolyte content of the tissue. The characteristic frequency of the Debye relaxation is 20 GHz, the same as for pure water; its amplitude is consistent

with the known water content of the tissue. These observations support two important conclusions. First, the microwave dielectric properties of tissue can be adequately predicted from measurements near 100 MHz and from the known dielectric properties of water. From an electric point of view, the tissue can be approximated by a suspension of nonconducting proteins in an electrolyte solution at these frequencies. Second, while a relatively few "bound" or motionally restricted water molecules are present in the tissue, the results indicate that they play no major role in the absorption of microwave energy by the tissue. It is concluded that the dielectric data contradict the hypothesis that most of the tissue water has motional properties significantly different from those in bulk water. (No refs.)

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13. ABSTRACT

This 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 meetings and conferences.

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