illness and malaise, indicating that rats previously unresponsive to microwave exposure develop saccharin aversion with an apomorphine stimulus. Repetitive irradiation with 65 mW/cm^2 for 1 hr following a 30-min drinking period had no effect on water consumption, indicating that decreased saccharin intake is a behavioral aversion to the novel stimulus and not due to the test chamber environment. It is concluded that the aversive response to saccharin solution after microwave irradiation is not the result of gastroenterologic disturbances and that it may be elicited when the core body temperature becomes hyperthermic or is raised to 40 C for ≥1 hr.

6244 THE COMBINED EFFECT OF AN SHF FIELD AND AN UNFAVORABLE MICROCLIMATE ON THE BODY. *(Eng.)* Zhuravlev, V. A. (No affiliation given). 6 pp.; 1978. [available through National Technical Information Services, Springfield, VA 22161, Document No. HC A03/MF A01]. (0 refs)

The combined effect of a super-high frequency electromagnetic field and an unfavorable microclimate on various biologic functions of female rats was investigated. One group of rats was irradiated for 1 hr/day by 10-cm microwaves at a power flux density of 5 mW/cm^2; after this, they were placed in a thermostat at an air temperature of 40 C and a relative humidity of 22-25% (air movement did not exceed 0.05 m/sec). A second group of rats was exposed to the unfavorable microclimate only under similar conditions. A control group was exposed neither to microwaves nor heat. The exposure period was 60 days for the first two groups. An increase in the number of erythrocytes and in hemoglobin concentration was noted in rats exposed to microwaves and heat, while rats exposed to heat alone only showed a tendency toward increased numbers of erythrocytes. Rats irradiated with microwaves also showed a lower blood viscosity than nonirradiated rats. Blood catalase activity decreased in both experimental groups, though more distinctly in microwave-irradiated rats. The percentage of reproducing females and the number of rats in a litter were lower in rats irradiated with microwaves than in rats treated with heat alone or control rats. Microwave-irradiated rats also showed more pronounced changes in internal organs than did rats from the other two groups. Weight coefficients of the liver and spleen were significantly lower in microwave-irradiated rats than in controls or rats exposed to heat alone. In the cardiac muscle, homogenation and fragmentation of muscle fibers coupled with minor subepicardial hemorrhaging were noted more frequently in response to microwaves plus heat, while circulatory disturbances dominated in rats subjected to heat alone. Signs of chronic venous plethora in the liver and spleen were more highly pronounced in response to microwaves in combination with heat.

6245 QUANTITATION OF MICROWAVE RADIATION EFFECTS ON THE HEAD AND EYES OF RABBITS, PRIMATES AND MAN. *(Eng.)* Kramar, P. O. (Bioelectromagnetics Res. Lab., Dept. Rehabilitation Medicine, Univ. Washington Sch. Medicine, Seattle, WA 98195). 3 pp.; 1978. [available through National Technical Information Service, Springfield, VA 22161, Document No. AD A058343]. (0 refs)

The effect of microwave irradiation on cataract formation and retrolental temperature was investigated in adult albino rabbits. The right eyes of five anesthetized rabbits were exposed to a 2,450-MHz "C" director in the near field at a power density of 300 mW/cm^2 for 5 min either every other day or every third day for a total of five exposures. The left eyes served as controls. Three cataracts developed in three rabbits exposed every other day to microwave radiation, whereas no cataracts developed in two rabbits exposed to the radiation every third day. Thus, it appears that 2 days are required between exposures to allow the lens to recover. Direct retrolental temperatures were measured in another group of adult albino rabbits exposed to 300 mW/cm^2 for 5 min. There was no progressive increase in the postirradiation temperatures, nor was there a consistent pattern of the preirradiation temperatures. However, the postirradiation temperatures were recorded between 42 and 46 C in all cases. Attempts to quantitatively determine ocular blood flow accurately in rabbits not exposed to microwaves were also performed, but only qualitative analysis was possible.

6246 DEPOSITION OF ELECTROMAGNETIC ENERGY IN ANIMALS AND IN MODELS OF MAN WITH AND WITHOUT GROUNDING AND REFLECTOR EFFECTS. *(Eng.)* Gandhi, O. P.; Hunt, E. L.; D'Andrea, J. A. (Dept. Electrical Engineering and Bioengineering, Univ. Utah, Salt Lake City, UT 84112). 11 pp.; 1978. [available through National Technical Information Service, Springfield, VA 22161, Document No. AD A058289]. (10 refs)

Generalized curves for whole-body absorption of electromagnetic energy by models of human beings are given as a function of frequency for free space, for electrical contact with the ground, and for the presence of reflecting surfaces. Based on these curves, generalized graphs for specific absorption rates (SAR) for rats and mice were drawn, and the results were shown to be in good agreement with experimental data. Peaks of absorption with and without grounding, respectively, were projected to be (31-34 MHz) and (62-68 MHz) times (1.75/height of the model in meters). It was also shown that tremendous enhancements in rates of energy deposition resulted for targets that were placed in proximity to reflecting surfaces. Energy deposition rates are given for models of man and for animals subjected to fields at a power density of 10 mW/cm^2 under various conditions of exposure, and SAR values as high as 35-70 times the basal metabolic rate are predicted for adult human beings at resonant frequencies. Measurements of the mean time to convulsion for 100-g rats exposed to incident waves at power densities of 3-20 mW/cm^2 confirmed some of the predictions of enhanced absorption in the presence of reflecting surfaces.

6247 EFFECT OF CONSTANT MAGNETIC FIELDS OF VARIOUS DIRECTIONALITY ON THE GROWTH RATE OF WHEAT SPROUTS. *(Eng.)* Bogatina, N. I.; Verkin, B. I.; Kordyum, V. A.; Kordyum, Ye. L.; Litvin, V. M. (No affiliation given). 5 pp.; 1978. [available through National Technical Information Service, Springfield, VA 22161, Document No. HC A03/MF A01]. (6 refs)

The effect of constant magnetic fields of varying polarity on the growth rate of wheat sprouts was investigated. Wheat grains placed on thin cotton balls in Petri dishes (at 23 ± 0.5 C) sprouted in the dark in man-made magnetic fields maintained up to 5 days. The earth's magnetic field was shielded with ferromagnetic screens by a net magnetic field with horizontal and vertical components of 0.2 and 0.5 mOe, respectively. The artificial fields, created by placing solenoids within the screen, had an instability of less than 0.1 mOe; the regular variation of the field was 0.1-1.0% of its value with time. The horizontal magnetic field substantially altered the growth pattern of the grains while the vertical field had no effect. The effects were less obvious on roots than coleoptiles. Orientation of the buds to the south with respect to the horizontal magnetic field accelerated the growth by 44%. Roots oriented to the north were longer than those oriented to the other directions. High intensity magnetic fields (2,570 Oe) produced inhibition of root growth directed along the field displayed by the central root. Further experiments are necessary to determine whether the effects of constant magnetic fields of varying polarity on the growth rate of wheat sprouts can be quantified.

6248 NEW SCIENTIFIC BRANCH ESTABLISHED FOR ELECTROMAGNETIC HYGIENE STUDY. *(Eng.)* Appenyanskiy, A. (Electromagnetic Hygiene Lab. Sanitary-Epidemiological Station, USSR). 4 pp.; 1978. [available through National Technical Information Service, Springfield, VA 22161, Document No. HC A03/MF A01]. (0 refs)

Regulations for exposure to electromagnetic fields associated with industrial, medical, scientific, and other applications in the USSR are reviewed. The regulations cover electrical fields at industrial frequencies (50 Hz), radiowaves, infrared radiation, and visible and ultraviolet light. Regulations for work safety at substations and around electric transmission lines state that exposure to an electric field of 5 kV/m is acceptable for a working day period and exposure to a 10-kV/m field for not more than 3 hr at a time.

6249 A QUANTITATIVE REVIEW OF HUMAN SUSCEPTIBILITY TO MAGNETIC FIELDS. *(Eng.)* Schiff, A. (Lawrence Livermore Lab., Univ. California, Livermore, CA). 31 pp.; 1978. [available through National Technical Information Service, Springfield, VA 22161, Document No. N79-11691]. (35 refs)

A review of the literature on human susceptibility to magnetic fields is presented. The results of this review suggest that exposure to the following types of magnetic fields should be avoided: alternating current fields in the body function frequency range at any magnetic intensity (0.3-10 Hz and 18-30 Hz); all frequencies for extended periods at intensities above 200 G; and all frequencies greater than 10 Hz at levels above 1 G for persons with cardiac pacemakers. The bibliography to this review includes 22 abstracted references.

6250 CELLULAR AND MOLECULAR EFFECTS AND THE MECHANISM OF ACTION OF MICROWAVE ELECTROMAGNETIC FIELDS ON BIOLOGICAL SYSTEMS. *(Eng.)* Arber, S. L. (No affiliation given). 17 pp.; 1978. [available through National Technical Information Service, Springfield, VA 22161, Document No. HC A03/MF A01]. (88 refs)

Cellular and molecular effects of microwaves on biologic systems are discussed. On the cellular level, two types of effects are observed: orientation or directed movement of unicellular animals and changes in physiologic functions. The first type of effect does not apparently have biologic significance. Mechanisms for the second type of effect are associated with the action of an electromagnetic field on subcellular structures and macromolecules. It has been demonstrated that cells absorb microwaves in the millimeter frequency range corresponding to the absorption bands of cellular components. Absorbed energy alters metabolic and biosynthetic processes and retards cell growth. An increase in membrane ion permeability in response to microwaves has been observed, which is a manifestation of the cell's nonspecific reaction to microwaves. It has also been observed that super-high frequency electromagnetic fields can alter enzyme activity; for example, a change in reaction rate was observed when a solution of lysozyme and its substrate was irradiated by a 10,000-MHz field. A review of various possible mechanisms for the high sensitivity of biologic systems to electromagnetic fields indicates that the biologic effects of microwaves are associated with the molecular level of organization of living systems.

MEETING ABSTRACTS

6251 BONE GROWTH IN ELECTRIC FIELDS (MEETING ABSTRACT). *(Eng.)* McClanahan, B. J. (Biology Dept., Battelle Pacific Northwest Lab., Richland, WA 99352); Kaune, W. T.; Phillips, R. D. *Health Phys* 35(6): 891; 1978. (0 refs)

The influence of a uniform alternating current electric field on the normal skeletal growth pat-

tern of rats was examined. Juvenile rats received whole body exposure to uniform, vertical 60-Hz electric fields at 100 kV/m for 30 days. There were no marked alterations in the general growth pattern of the exposed animals compared to controls maintained under similar conditions. Bone growth rate, measured by tetracycline labeling, morphology of lumbar vertebrae and tibias and cortical bone area and marrow space area of tibias were not disturbed by exposure to the electric fields.

6252 FERTILITY AND TERATOLOGY IN RATS EXPOSED TO 100 kV/m ELECTRIC FIELD (MEETING ABSTRACT). *(Eng.)* Cantone, A. (Dept. Physiology and Nutrition, Medical Faculty, Univ. Milan, Milan, Italy); Viola, D.; Margonato, V. *Teratology* 19 (2): 22A; 1979. (0 refs)

To investigate the effects of electric fields on fertility and fetal development male rats were exposed to a 100 kV/m electric field during 48 days, 8 hr/day. Some were mated with unexposed females after 14, 35, or 48 days of exposure and some were sacrificed after 16, 32, and 48 days. In sacrificed rats, volume and weight of testes were normal. Oligospermia was detected in 20% after 16 days and in 12.5% after 48 days of exposure in comparison to 14.3% in controls; no azospermia or oligozoospermia were detected. Morphology and motility of spermatozoa were normal. In females mated with exposed males the fertility was not affected. At the cesarean inspection on day 20 of pregnancy, the total reabsorptions, early and late, were normal after 14 and 48 days of exposure; on day 35 of exposure reabsorptions were 10.8% in exposed and 7.9% in controls. The number of fetuses was normal, while the weight was generally lower in fetuses from exposed than from control animals; a significant difference was seen only after 35 days (3.86 ± 0.14 g in controls versus 3.44 ± 0.11 g). In fetuses from exposed animals, external, visceral, and skeletal examinations showed no major malformations; only in fetuses that showed weight reduction were some ossification centers delayed.

6253 MICROWAVES ALTER THERMOREGULATORY BEHAVIOR (MEETING ABSTRACT). *(Eng.)* Adair, E. R. (John B. Pierce Foundation, New Haven, CT 06519). *Fed Proc* 38(3, Part 2): 1295; 1979. (0 refs)

The minimal incident microwave energy that alters thermoregulatory behavior was determined, and the role of skin heating in this effect was assessed. Squirrel monkeys, trained to regulate environmental temperature (T_a) behaviorally, were exposed in the far field of a horn antenna to 10-min periods of 2,450 MHz continuous wave microwaves. Incident power densities ranged from 1 to 22 mW/cm^2. Controls included exposure to infrared radiation of equivalent incident energy and no radiation exposure. Normally, squirrel monkeys select a T_a of 34-36 C; microwave exposures at 6-8 mW/cm^2 stimulated selection of a lower T_a. Skin and rectal temperatures remained stable even at 22 mW/cm^2 where preferred T_a was as much as 4 C below control levels. No comparable reduction in selected T_a occurred during infrared radiation of equal incident energy. These results suggest that changes in thermoregulatory behavior triggered by absorbed microwaves result from stimulation of internal thermoreceptors whereas responses to infrared radiation result primarily from stimulation of receptors in the skin.

6254 BIOLOGICAL EFFECTS OF MICROWAVES ON ANIMALS. REPORT 2: ENVIRONMENTAL TEMPERATURE--SURVIVAL TIME RELATIONSHIP (MEETING ABSTRACT). *(Jpn.)* Anzai, I. (Public Hygiene Div., Dept. Medicine, Kanazawa Univ., Kanazawa City, Ishikawa-ken, Japan); Irie, S.; Higuchi, R.; Komoriya, U.; Okada, A.; Moroji, T. *Jpn J Hyg* 33(1): 243; 1978. (0 refs)

The relationship between body weight and environmental temperature on animal survival time during microwave irradiation was studied in Wistar rats. At 50 mW/cm^2 all rats died, but the length of time the rat tolerated the radiation increased with its average body weight: five 252-g rats survived 12.6 ± 1.9 min; five 312-g rats survived 15.8 ± 1.2 min; five 505-g rats survived 23.2 ± 1.1 min; and five 595-g rats survived 25.2 ± 0.7 min. Rats exposed to 10 mW/cm^2 radiation survived longer: five 315-g rats survived 40.6 ± 2.1 min, and four 297-g rats survived 73.5 ± 11.6 min. One 297-g rat and all five of the 462-g rats survived past the 180-min limit of administered 10 mW/cm^2 radiation. The lower the environmental temperature during the 50 mW/cm^2 irradiation, the longer was the survival time of the rats; survival time at 7 C was 29-33 min, at 12 C it was 28-32 min, at 17 C it was 20-22 min, and at 22 C it was 11-13 min. Rectal temperature at the time of death increased as the survival times decreased.

6255 BIOLOGICAL EFFECTS OF MICROWAVES ON ANIMALS. REPORT 3: EFFECTS ON BLOOD COMPONENTS (MEETING ABSTRACT). *(Jpn.)* Irie, S. (Public Hygiene Div., Dept. Medicine, Kanezawa Univ., Kanezawa City, Ishikawa-ken, Japan); Higuchi, R.; Komoriya, U.; Anzai, I.; Okada, A.; Moroji, T. *Jpn J Hyg* 33(1): 244; 1978. (0 refs)

The effects of 10 mW/cm^2 microwave radiation on the blood components of Wistar rats (average weight of 462 g) was studied. Six blood samples were taken: one before the irradiation, and one, 30 min, 60 min, 90 min, 120 min, and 180 min after. The rectal temperature increased until 30 min and then remained constant at 35.5 C in the control rats; the temperature of the test subjects rose to 39.6 C 90 min after the irradiation and remained constant thereafter. The hematocrit level of both control and test subjects decreased slightly after 180 min. The red blood cell count (RBC) in the controls decreased but there was no difference between the

pre-irradiation levels and the post-180 min irradiation levels; there was no RBC change in the test subjects. Acidophilic cells in controls decreased up to 120 min after and then leveled. The levels of the test subjects decreased to 9 ml^3 after 180 min. Both groups had significant decreases in white blood cell counts (WBC) after 180 min: there was a 44.9% decrease in WBC in the controls and a 52.5% decrease in the test subjects but the percentage difference between the two groups throughout the study was not significant. After 180 min there was a slight decrease in the lymphocyte count for the controls but the test subjects had a significant decrease to 46%. Neutrophils in both groups increased over time, with 3-lobed nuclei increasing more than 2-lobed nuclei. It is concluded that low-level, long-term microwave radiation affects the production of blood cells, particularly of leucocytes.

6256 STUDIES OF THE BLOOD-BRAIN BARRIER IN MICE AFTER EXPOSURE TO RF RADIATION, USING FLUORESCEIN AND UNUSUAL AMINO ACIDS (MEETING ABSTRACT). *(Eng.)* Spackman, D. H. (Pacific Northwest Res. Foundation, Fred Hutchinson Cancer Res. Center, Univ. Washington, Seattle, WA 98104); Riley, V.; Guy, A. W.; Chou, C-K. *Fed Proc* 38(3, Part 1): 357; 1979. (0 refs)

The increased permeability of the blood-brain barrier (BBB) that has been reported in rats after RF radiation (RFR) at low power densities was studied in mice using fluorescein (FCN) and amino acids not normally found in mice, as test compounds (T-cpds). Five min after intraperitoneal injection of the T-cpds, the mice were bled, killed, perfused, and the brain removed. Clear, deproteinized extracts of plasma and of brain homogenates were analyzed for FCN with a spectrofluorometer, and for amino acids with an amino acid analyzer. The concentration of T-cpds in brain and plasma were compared in control mice and in those given RFR. For RFR, mice were placed in a styrofoam holder mounted in a circularly polarized waveguide. Separate groups were exposed to either sham, continuous wave, or pulsed (100 pulses/sec, 10 μsec/pulse) radiation at 918 MHz for 30 min. Average power densities of 2.5, 33, and 132 mW/cm^2 were tested (average specific absorption rates of 0.52, 6.93, and 27.7 W/kg, respectively). Following sham or radiation exposure, plasma and brain samples were analyzed. No significant increase in permeability of the BBB in radiated mice as compared to non-irradiated controls was detected. No significant increase in permeability of the BBB in radiated mice as compared to non-irradiated controls was detected. The effects of heat and of several chemical compounds on the BBB were also studied in non-irradiated mice.

6257 MICROWAVE IRRADIATION FOR BRAIN ENZYME INACTIVATION: IMPORT OF POWER DISTRIBUTION (MEETING ABSTRACT). *(Eng.)* Stavinoha, W. B. (Dept. Pharmacology, Univ. Texas Health Science Center at San Antonio, San Antonio, TX 78284); Deam, A. P.; Modak, A. T.; Meyerson, L.; Dones, H.; Blank, L. *Fed Proc* 38(3, Part 1): 374; 1979. (0 refs)

Valid analysis of substances in the rodent brain that are rapidly metabolized by enzymes requires the swift termination of enzymatic action. This can be accomplished by properly heating with microwave irradiation. The assessment of the time of enzymatic inactivation in a region of the brain depends upon (1) a knowledge of the area of primary microwave power deposition; (2) diffusion of temperature in the brain; and (3) the combination of temperature and time required to inactivate the pertinent enzyme. Theoretic calculations of power distribution were followed by measurement of temperature distribution in mouse brain. The diffusion properties were computed in two dimensions for a cylindric rod in a material having the thermal properties of brain. Time and temperature requirements of the four enzymes of the dopamine system were studied and only catechol-*O*-methyl transferase was found to be difficult to inactivate and required 275 msec irradiation to a temperature of 86 C to reduce activity to 18% of control. Regional values for dopamine were the same for animals sacrificed by decapitation or heating except in the striatum where rapid heating yielded 8,440 ng/g as compared to a decapitation value of 4,700 ng/g.

6258 STUDIES CONCERNING THE EFFECTS OF LOW DOSAGE PRENATAL 6000 MHz MICROWAVE RADIATION ON GROWTH AND DEVELOPMENT IN THE RAT (MEETING ABSTRACT). *(Eng.)* Jensh, R. P. (Dept. Anatomy, Thomas Jefferson Univ., Philadelphia, PA); Vogel, W. H.; Ludlow, J.; McHugh, T. *Teratology* 19(2): 32A; 1979. (0 refs)

To investigate the effects of low dose prenatal microwave radiation on growth and development in the rat 12 pregnant Wistar rats were exposed to 35 mW/cm^2 of microwave radiation at a frequency of 6,000 MHz throughout gestation. Total mean exposure time was 102.3 hr. Four pregnant rats served as concurrent controls and were placed in the anechoic chamber for similar time periods, while 30 pregnant rats were baseline controls. Power levels in excess of 35 mW/cm^2 had been determined previously to cause an increase in body temperature as measured by a thermocouple probe. All animals were killed on day 22 of gestation. The uteri were exteriorized, and fetal and placental positions and weights and resorption sites were recorded. Following fixation in Bouin's fixative all fetuses were dissected using Wilson's cross-sectional technique to determine the abnormality rate. Data were compared among 117 exposed fetuses, 24 concurrent control fetuses, and 314 baseline control fetuses for the following parameters: maternal weight gain, maternal blood elements (hematocrit, hemoglobin, white blood cell count), litter size, fetal weight, placental weight, resorption rate, and abnormality rate. No significant effects due to exposure to 6,000 MHz microwave radiation at

35 mW/cm^2 were observed using these indices of prenatal growth and development.

6259 EXPERIMENTS IN ELECTRICAL STIMULATION OF BONE GROWTH (MEETING ABSTRACT). *(Eng.)* Paterson, D. (Dept. Orthopedic Surgery, Adelaide Children's Hosp., North Adelaide, South Australia, Australia); Tilbury, R. F. *Aust NZ J Med* 9(1): 97; 1979. (4 refs)

The construction of a surgical model of delayed union and the use of this model for bone growth stimulation experiments are described. Twenty-two pairs of dogs were subjected to stimulation, one of each pair had an active stimulator and one had an inactivated stimulator inserted. Three different methods of assessment of bone healing were used, i.e., clinical, histologic, and nuclear scanning. The results of each method of assessment were calculated separately and then together. The overall result when all three criteria were taken together was that there was a distinct positive association between active stimulation and the superiority of healing ($n=21$, $T=48$, $p<0.02$).

6260 THE GROWTH MODULATING EFFECTS OF NON-THERMAL, NON-IONIZING RADIATION (RADIO-WAVES, PULSED MAGNETIC RADIATION) ON NEUROBLASTOMA DIFFERENTIATION, TUMOR GROWTH AND EMBRYONIC MOUSE PALATAL DEVELOPMENT (MEETING ABSTRACT). *(Eng.)* Regelson, W. (Medical Coll. Virginia, Richmond, VA 23298); West, B.; DePaola, D.; Lieb, R.; Pilla, A. *Proc Am Assoc Cancer Res* 20: 118; 1979. (0 refs)

Neuroblastoma cells were placed in homogeneous time varying magnetic fields (2 G average) using 4-inch air gap coils. The induced current wave form (of μA/cm^2 level) was designed to either excite only surface or surface-coupled transport processes. Significant differences in the degree of dendritic outgrowth versus multiplication as a function of induced current wave forms were detected that were similar to those reported for calcium ionophores and for polar solvents in inducing tumor cell retransformation. Additional studies were conducted using 27 MHz (diapulse) whole body radiation in mice to investigate the effects on the growth rates of transplanted Lewis lung tumor. Inhibition or acceleration of tumor growth was dependent on pulsed frequency timing and type of pulsed frequencies used. Fourteen-day-old mouse embryo palatal explants were found to show in vitro epithelial destruction or chondrometaplasia depending on whether high or low frequency magnetic pulses were administered. These effects were non-thermal and establish a biologic role for nonionizing radiation that deserves further exploration utilizing different wave forms and frequency windows.

6261 EFFECTS OF PULSED ELECTROMAGNETIC FIELD ENERGY (DIAPULSE) ON THE NORMAL COMMON PERONEAL NERVE IN RATS (MEETING ABSTRACT). *(Eng.)* Raji, A. R. M. (Dept. Anatomy, Royal Free Hosp. Sch. Medicine, London, England). *J Anat* 127(3): 667; 1978. (1 ref)

The effects of pulsed electromagnetic field (Diapulse) on the normal common peroneal nerve were studied in 12 rats. Each animal received 400 pulses/sec for 15 min daily for a period varying between 1 and 8 wk. A control group of 12 rats was subjected to mock treatment of similar duration, i.e. they were in the machine but not subjected to a pulsed electromagnetic field. Paired, treated and untreated animals were sacrificed at intervals varying from 1 to 8 wk. The common peroneal nerves were subjected to quantitative and qualitative analysis using both light and electron microscopy. All specimens were fixed in buffered 4% glutaraldehyde, post-fixed in buffered 1% osmium tetroxide and embedded in Araldite. Thick 1-μm sections were stained in 1% toluidine blue in 1% borax; the ultrathin sections were stained with a saturated solution of uranyl acetate and Reynolds' lead citrate. The results indicated that the pulsed electromagnetic field had no morphologic effect on the normal nerves.

6262 ELECTRICAL PERTURBATION STIMULATES PROLIFERATION IN G_1 AND G_2 ARRESTED CELLS (MEETING ABSTRACT). *(Eng.)* Bourret, L. A. (Univ. Connecticut Sch. Dental Medicine, Dept. Oral Biology, Farmington, CT 06032); Rodan, G. A. *J Dent Res* 58 (Special Issue A): 416; 1979. (1 ref)

Electrical perturbations (EP) produced by oscillating external electric fields stimulate the incorporation of tritiated thymidine into cartilage cell DNA. In the present study the relationship of the EP effect to cell adherence, serum, and the cell cycle was examined. It was found that cells grown in siliconized tubes were susceptible to electrical stimulation. Electrical stimuli did not replace the serum requirements for growth and had no effect when cells were grown in the total absence of serum. Serum was, however, not required during exposure to EP. Growth enhancement by electrical stimuli and serum were additive at all serum concentrations, suggesting independent effects. In partially synchronized cells electrical stimuli increased by 35% the number of cells going into S phase without affecting the length of the G_1 phase (20 hr). In randomly growing cells electrical stimuli produced a burst of DNA synthesis at 20 hr. The number of G_1 arrested cells susceptible to electrical stimulation remained approximately constant throughout growth in culture. Electrical stimuli also acted on G_2 arrested cells promoting cell division during the lag phase and producing an increase in cell number 4-6 hr after exposure of randomly growing cells to EP. The findings demonstrate the ability of the electrical perturbation to shift a subpopulation of cells arrested in G_1 and G_2 to the proliferative mode.

6263 MECHANISM OF THE COMPRESSION OF BLACK LIPID MEMBRANES BY AN ELECTRIC FIELD

(MEETING ABSTRACT). *(Eng.)* White, S. H. (Dept. Physiology, Univ. California, Irvine, CA 92717). *Biophys J* 25(2, part 2): 9a; 1979. (2 refs)

Transmembrane electric fields decrease the thickness of planar bilayer membranes (black films) by displacing alkane solvent from the bilayer into the annulus (torus) and microlenses. The mechanism underlying this effect was investigated. It was found that the electric field produces an electrostrictive increase in the pressure acting on the alkane molecules in the bilayer but not in the annulus. This raises the chemical potential of the alkane in the bilayer relative to the annulus. Since the bilayer alkane must remain in equilibrium with the annulus alkane, the bilayer alkane concentration decreases to reduce the chemical potential to the annulus value. The consequent decrease in bilayer thickness would be small if the alkane formed an ideal solution with the bilayer. However, the bilayer solution is highly non-ideal as was found by controlling the activity of n-decane in the torus of glyceryl monooleate bilayers using squalene, which is insoluble in the bilayer. The relation between torus decane mole fraction (X_{DEC}) and bilayer thickness is such that large changes in thickness occur for relatively small changes in X_{DEC}. Thus, small changes in alkane chemical potential have large effects on thickness.

6264 EFFECT OF PULSED MAGNETIC RADIATION (DIAPULSE) ON EMBRYONIC MOUSE PALATE (MEETING ABSTRACT). *(Eng.)* Lieb, R. J. (Medical Coll. Virginia, Richmond, VA 23298); Regelson, W. L.; West, B.; DePaola, D. P.; Jordan, R. L. *J Dent Res* 58(Special Issue A): 213; 1979. (0 refs)

The effect of pulsed nonionizing radiation (radiowaves) on palate development in the mouse was investigated. A variety of radio frequency generators was used to study the nonthermal effects of nonionizing radiation. Palates from 14 day postconception Swiss Webster mice were explanted in Tyrode's horse serum (1:1) and irradiated for 20 min utilizing a pulsed nonionizing source (Diapulse) with a carrier frequency of 27 MHz at either 975 peak W with a pulse frequency of 600 pulses/sec on a 3.9% duty cycle (E_1) or at 493 peak W with a pulse frequency of 160 pulses/sec on a 1% duty cycle (E_2). Control tissues were treated in a similar manner except for the radiation procedure. All palates were cultured on solidified nutrient agar for 24 hr at 37 C with 5% CO_2 in air. The culture medium was composed of 1% agar, 1% glutamine, 10% dialyzed fetal calf serum, 6% chick embryo extract and 50 µ/ml penicillin-streptomycin in Eagle's basal medium. Palates were then harvested and prepared for microscopy. Tissue from E_1 exhibited marked depletion of oral and medial edge epithelium, while tissue from E_2 showed development of cartilage within the mesenchymal compartment. The results indicate that pulsed nonionizing radiation results in epithelial destruction at higher frequencies and in chondrometaplasia of palate mesenchyme at lower frequencies. This effect is independent of temperature and differs from microwave effects.

6265 THE EFFECTS OF ELECTRIC FIELD ON THE IMMUNE SYSTEM OF EXPOSED MICE (MEETING ABSTRACT). *(Eng.)* Morris, J. E. (Biology Dept., Battelle Pacific Northwest Lab., Richland, WA 99352). *Health Phys* 35(6): 890-891; 1978. (0 refs)

Swiss-Webster male mice were exposed for 30 and 60 days in a 60-Hz, 100 kV/m electric field to determine the effect of exposure on humoral and cellular components of the immune system. Quantitation of serum IgG and IgM with a double-antibody radioimmunoassay revealed no significant difference in the levels of these immunoglobulins between exposed and sham-exposed mice for the two time periods. In conjunction with the serum studies, the relative concentrations of T and B lymphocytes in the peripheral blood were measured using the spontaneous rosette assay and the binding of fluorescent-labeled goat anti-mouse immunoglobulins. No significant difference was observed in the distribution of these lymphocyte populations in exposed and sham-exposed mice.

6266 PHYSIOLOGIC RESPONSE OF RATS TO COLD STRESS AFTER EXPOSURE TO 60-HZ ELECTRIC FIELDS (MEETING ABSTRACT). *(Eng.)* Hilton, D. I. (Biology Dept., Battelle Pacific Northwest Lab., Richland, WA 99352); Phillips, R. D.; Free, M. J.; Lang, L. L.; Chandon, J. H.; Kaune, W. T. *Health Phys* 35 (6): 891; 1978. (0 refs)

In two experiments, the responses of the hypothalamo-pituitary-adrenal, thermoregulatory, and cardiovascular systems were assessed in rats subjected to cold stress after exposure to uniform 60-Hz electric fields of 100 kV/m for 1 mo. In the first experiment, plasma corticosterone levels were measured following exposure or sham exposure with the animals maintained at room temperature (~23 C). Corticosterone levels were also measured in rats subjected to cold stress (-13 C for 1 hr) immediately after the exposure period. Plasma corticosterone levels in the cold-stressed animals were significantly higher than in those kept at room temperature; however, there were no significant differences between exposed and sham-exposed animals for either the ambient or cold-stress situations. The second experiment followed the same field exposure and cold-stress protocol, only measurements of heart rate, deep colonic temperature, and skin temperature were made before, during, and after cold-stressing. The results for exposed and sham-exposed animals were essentially identical, failing to demonstrate any effect of electric field exposure on thermoregulatory and cardiovascular response to cold stress.

6267 TERATOGENICITY OF 27.12 MHz RADIOFREQUENCY RADIATION IN RATS (MEETING ABSTRACT). *(Eng.)* Lary, J. M. (Physical Agents Effects Branch, NIOSH, Cincinnati, OH); Conover, D. L.; Foley, E. D. *Teratology* 19(2): 36A; 1979. (0 refs)

To investigate the teratogenicity of 27.12 MHz radio frequency radiation, eight groups of 16 to 28 pregnant Sprague-Dawley rats were irradiated

at 27.12 MHz in a radio frequency (RF) near-field synthesizer facility operating in the dominant magnetic field mode at a magnetic field strength of 55 A/m. The groups were irradiated on gestation days 1, 3, 5, 7, 9, 11, 13, or 15, respectively. Dams were exposed one at a time until their rectal temperature reached 43.0 ± 0.1 C (about 20 to 40 min exposure duration). Eight matching control groups of 10 to 13 pregnant rats were sham-irradiated for 30 min at 0 A/m. An additional group of 29 pregnant rats was left untreated in the animal quarters. Sham control groups were combined to form early (days 1, 3, 5), middle (days 7, 9, 11), and late gestation (days 13, 15) control groups for statistical comparisons with the experimental groups and untreated control group. All dams were sacrificed on gestation day 20 (sperm day = day 0) and examined by standard teratology procedures. No significant differences were found between sham-irradiated controls and untreated controls. No significant effects were found in litters irradiated during preimplantation development (days 1, 3, or 5) compared to sham controls except for an increased incidence (3%) of grossly malformed fetuses on day 3. Rats irradiated during organogenesis (days 7 through 15) had a significant increase in the incidence of gross malformations and a significant decrease in fetal weight and fetal crown-rump length. Fetuses exposed on gestation day 9 appeared to be most sensitive to RF radiation (67% incidence of gross malformations). Postimplantation loss was also increased in rats irradiated on days 7 or 9.

6268 ENHANCEMENT OF NATURAL KILLER CELL ACTIVITY IN MICE AFTER EXPOSURE TO MICROWAVE RADIATION (MEETING ABSTRACT). *(Eng.)* Schlagel, C. (Naval Medical Res. Inst., Bethesda, MD 20014); Folks, T.; Woody, J.; Leach, W.; Sulek, K. *Fed Proc* 38(3, Part 2): 915; 1979. (0 refs)

The natural killer (NK) activity of spleen cells from Balb/c and CBA/J was assessed after exposure of these mice in an environmentally-controlled waveguide facility to a 30-min continuous exposure to microwaves at a frequency of 2,450 MHz and a forward power of 0.4 W and 0.6 W. Spleen cells were incubated with the ^{51}Cr labeled YAC-1 tumor target cells for 6 hr and the percent net ^{51}Cr release and the cytotoxic index (CI) were calculated as a function of NK activity. Spleen cells from sham-exposed adult CBA/J mice showed a CI of 37% whereas microwave-exposed littermate CBA/J mice showed a CI of 50.2% ($P<0.01$). Ontogeny studies carried out in Balb/c mice revealed that spleen cells from 8- and 13-day-old control Balb/c mice had NK activity of 5.6 ± 0.9 and 0.6 ± 1.3 CI, respectively. After exposure to microwaves, littermate 8- and 13-day-old Balb/c spleen cells gave CI of 10.1 ± 1.4 and 14.7 ± 7.4. Kinetic studies revealed that this increase in NK activity could be seen as early as 20 min after exposure to the microwaves to as late as 6 days after exposure. Experiments were performed to determine whether the increase in NK activity was due to an increase in the frequency of NK cells or to an inherent increase in the functional activity of these cells.

6269 THE EFFECT OF LOCAL HIGH FREQUENCY HYPERTHERMIA ON URINARY BLADDER CARCINOMA--EXPERIMENTAL AND CLINICAL STUDIES (MEETING ABSTRACT). *(Eng.)* Harzmann, R. (Dept. Urology, Univ. Tubingen, Calwer Str. 7, D-7400 Tubingen, W. Germany); Bichler, K. H.; Altenaehr, E.; Gericke, D. *Urol Res* 7(1): 40-41; 1979. (3 refs)

Experimental and clinical studies on the effect of local high frequency hyperthermia in the treatment of urinary bladder carcinoma are reviewed. The clinical use of hyperthermia for the treatment of urinary bladder carcinoma has yielded contradictory data. The effect of local hyperthermia on urinary bladder carcinoma was investigated experimentally in 80 rabbits with implanted Brown-Pearce carcinoma. Hyperthermic infusion of the bladder does not produce homogeneous warming of the bladder wall and therefore high frequency local irradiation was performed using two external electrodes and later by means of a transurethral probe. A high frequency long-wave current was used and a transurethrally inserted Teflon-insulated thermocouple was employed for temperature monitoring. The most efficient temperature was found to be 43 C for a period of 30-60 min. The heat-treated animals showed significantly smaller tumor volumes, less frequent metastases, and prolonged survival periods compared with controls. Transplantation of previously treated tumors resulted in a regrowth rate of 20% compared with 96% for untreated tumors. In a clinical study, 15 patients with urinary bladder carcinoma were treated by transurethral high-frequency heat application using an optically controlled probe. Edema and blanching of the tumor were observed as well as subsequent reduction in size. In 3 cases the tumor disappeared completely and in an additional 8 cases there was substantial improvement. Histology showed cell-cluster necrosis and hyalinization of the stroma in three cases. The best results were obtained in undifferentiated solid urothelial tumors. Some transient swelling of healthy epithelium occurred but without permanent damage.

6270 TREATMENT OF URINARY BLADDER CARCINOMAS WITH LOCAL HIGH-FREQUENCY (HF) HYPERTHERMIA (MEETING ABSTRACT). *(Eng.)* Harzmann, R. (Dept. Urology, Univ. Tubingen, Tubingen, W. Germany); Bichler, K. H.; Gericke, D.; Altenaehr, E.; Flachenecker, G. *Proc Am Assoc Cancer Res* 20: 113; 1979. (1 ref)

The ability of local high-frequency (HF) hyperthermia to guarantee homogeneous heating of the bladder wall was investigated. A special apparatus was constructed, using a teflon-insulated, optically-controllable active internal electrode and a belt-shaped inactive outer electrode. Male rabbits (76) with transplanted urinary Brown-Pearce carcinomas and 10 normal rabbits received treatment with HF-hyperthermia (43 C, 30 min). Tumor-bearing animals (20)

served as untreated controls. Six female beagles with invasive carcinomas of the urinary bladder induced by transurethrally-applied pellets and injections of chemical carcinogens received the same therapy. Rabbits with carcinomas that had been treated by local hyperthermia had significantly smaller tumors, fewer metastases, and a longer survival time than untreated animals. Urinary bladder cancer in dogs treated with hyperthermia yielded identical macroscopic findings. Histologically, the tumors necrotized gradually without lasting side effects on the healthy tissue. Because of these findings, 28 patients with undifferentiated advanced carcinomas of the urinary bladder were treated by the same technique. Cluster-cell necroses, seen 7 days after treatment, were followed by subtotal or total necrosis and pronounced stroma hyalinosis.

6271 SELECTIVE TUMOR HEATING BY SHORTWAVE RADIOFREQUENCY (RF) (MEETING ABSTRACT). *(Eng.)* Auda, S. P. (Univ. Maryland, Dept. Surgery, Baltimore, MD); Steinert, H. R.; Elias, E. G. *Int J Radiat Oncol Biol Phys* 5(Suppl. 1): 31; 1979. (0 refs)

Experimental tumors were treated with external high frequency dielectric heating to investigate any selectivity among tumor mass, subcutaneous tissue, and systemic temperatures. Methylcholanthrene-induced sarcoma cells were inoculated into the muscles of the posterior thigh of isologous Fisher rats. At day 14 when the size of the tumor mass averaged 1.10 cm^3, radio frequency (RF) dielectric heating was locally applied to the tumor-bearing area. A fixed frequency of 13.56 MHz was used. The power needed to bring the tumor temperature to 43 C or above ranged from 0.5 to 0.8 W/cm^2. The temperature was gradually increased to 43 C and maintained at or above that level for 1 hr. Thermocouple probes were inserted directly into the subcutaneous tissue immediately above the tumor and into two distinct areas of the tumor. Systemic temperature was monitored via a mercury thermometer inserted into the rectum. Temperature recordings were taken at 5-min intervals during which time the power was turned off to avoid RF interference and to allow thermal equilibrium between the probe and the tissue. The results indicated that there was a high selective temperature gradient with tumor mass. A highly statistical significance, $p<0.002$, was found comparing the tumor mass, subcutaneous tissue, and systemic temperatures using Scheffe's test. The systemic temperature was minimally elevated throughout the treatment. In a group of animals without tumors, treated in the same fashion, there was no significant difference between the temperatures measured in the subcutaneous tissue and in two different sites in the thigh muscle mass. Histologic investigation performed to evaluate both tumor and normal tissue damage indicated no tumor regression at the frequency employed.

6272 RESONANT INTERACTIONS BETWEEN BIOLOGICAL MOLECULES (MEETING ABSTRACT). *(Eng.)* Van Zandt, L. L. (Purdue Univ., West Lafayette, IN 47907). *Biophys J* 25(2, part 2): 186a; 1979. (0 refs)

Forces between localized, oscillating vibrations on molecules show strongly resonant dependence on the relative frequencies of the two oscillators; i.e. there is a force between the vibrating parts of two molecules if the frequencies are the same but none if the frequencies are different. A vibrating site on a large molecule can attract another specific type of molecule out of a medium, one that has a vibrational mode at the same frequency, without influencing other types of molecules in the medium. These resonant forces are thus highly selective. Other pairs of molecules could similarly interact using vibrations at a different frequency. In a complex medium such as a cell, many different types of interactions could be assisted by these resonant forces without interfering with each other. These forces could be useful in assisting some metabolic reactions since they are vulnerable to selective suppression or enhancement by externally applied electromagnetic radiation of correspondingly specific frequencies.

6273 BIOMAGNETIC RESEARCH AT THE LAWRENCE BERKELEY LABORATORY (MEETING ABSTRACT). *(Eng.)* Tenforde, T. (Biology and Medicine Div., Lawrence Berkeley Lab., Univ. California, Berkeley, CA 94720); Gaffey, C.; Yang, T.; Raybourn, M.; Roots, R.; Farinato, R.; *et al.* *Biophys J* 25(2, part 2): 166a; 1979. (0 refs)

Facilities have been developed at the Lawrence Berkeley Laboratory for large-scale experimentation on magnetic field effects in whole-animal, cellular, and molecular systems. Physiologic studies on small mammals and organ systems exposed to fields of ≤20 kG strength included measurements of deep-body temperature via telemetry, cardiac activity, nerve impulse conduction, behavioral tests, and visual function. Results indicated a strong effect of direct current magnetic fields on the electrocardiogram, with a sixfold increase in the T-wave amplitude occurring in a 20 kG field. No magnetic effects have yet been observed for other physiologic parameters under investigation. Studies are also being carried out to assess magnetic field effects on the growth and development of cultured mammalian cells, *Tribolium confusum* beetles, and *Zea mays* corn seeds. The possibility that conformational changes occur in supercoiled double-helical DNA as a result of alignment in strong magnetic fields is being studied by gel electrophoresis and electro-optical birefringence techniques. Preliminary results in each of these research areas are reported.

6274 SINGLE DOMAIN PARTICLES AND MAGNETOTATIC BACTERIA (MEETING ABSTRACT). *(Eng.)* Bean, C. P. (General Electric Corporate Res. & Development, P.O. Box 8, Schenectady, NY 12301). *Biophys J* 25(2, part 2): 216a; 1979. (2 refs)

Past research discovered a class of anaerobic bac-

teria that exhibit a magnetotactic response in the earth's magnetic field. Electron microscope studies coupled with x-ray emission measurements revealed chains of iron-rich particles in the body of the bacteria. It was suggested that the chains might serve as magnetic dipoles to provide an orienting torque in a magnetic field. It has been pointed out that the particles might be single magnetic domains. On this hypothesis it was possible to write an equation of motion for the passive orientation of the bacteria as $\theta = M_s B_o V \sin\theta / 8\pi\eta R^3$ where θ is the angle between the field B_o and the moment associated with a magnetization M_s in a saturated ferromagnet of volume V. The bacterium is approximated as a sphere of radius R in a fluid of viscosity η. For reasonable parameters the volume of Fe_3O_4 required to accomplish rotations in 1 min in the earth's field would amount to only two spheres ~400Å in diameter or four spheres ~300Å in diameter, etc. The observed electron dense regions are significantly larger. The theory of the magnetization of "chains of spheres" of magnetic single domains gives specific values for the coercive force (~350 Oe for a chain of two spheres of magnetite) and predicts a nonmonotonic dependence of coercive force on the angle of the applied field relative to the chain.

6275 DEVELOPMENTAL TOXICOLOGY STUDIES WITH 60-HZ ELECTRIC FIELDS (MEETING ABSTRACT).
(Eng.) Sikov, M. R. (Battelle, Pacific Northwest Lab., Richland, WA 99352); Montgomery, L. D. *Health Phys* 35(6): 890; 1978. (0 refs)

A series of replicate studies were undertaken to determine the effects of exposure to uniform 60-Hz electric fields (100 kV/m) on reproduction and on fetal and postnatal growth and development in the rat. In the first experiment it was found that a 6-day exposure prior to and during mating did not affect the reproductive performance of either males or females. Continued exposure of the mated females through 20 days of gestation, to a total of about 30 days, did not affect the size or morphology of the fetuses. A similar 30-day exposure of the males and of the unmated females did not affect their mating performance or fertility on subsequent testing. In the second experiment, exposure of the pregnant rat was begun on day 0 of gestation and continued until the resulting offspring reached 8 days of postnatal life. This 30-day exposure did not produce significant effects on the growth, survival, or neuromuscular development of the offspring. Tests of the reproductive integrity of the offspring disclosed no deficits. A third experiment involved a 30-day exposure, beginning at 17 days of gestation. Although this study is still in progress, evaluations of the first two replicates have not indicated any significant alterations.

6276 DESIGN OF EXPOSURE SYSTEMS FOR ELF ELECTRIC FIELD BIOEFFECTS RESEARCH (MEETING ABSTRACT).
(Eng.) Kaune, W. T. (Battelle, Pacific Northwest Lab., Richland, WA 99352); Decker, J. R.; Phillips, R. D.; Gillis, M. F. *Health Phys* 35(6): 890; 1978. (0 refs)

Two systems for exposure and sham-exposure of large numbers of rats and mice to uniform, vertical, 60-Hz electric fields have been constructed. The rat system contains four racks of four rectangular 1.0 m x 2.2 m exposure-electrodes that are stacked vertically with a separation between adjacent electrodes of 0.41 m. Any two of the four exposure racks may be energized to a maximum field strength of 150 kV/m. Each exposure electrode is equipped with 24 Lexan cages, each of which holds a single rat. The cage floor is a stainless steel screen that serves as one electrode. The system for watering animals is contained entirely within the electrode and does not protrude above the cage's floor, thereby preventing distortion of the exposure field and electrical shock or discharge as the animal drinks. The total capacity of the system is 288 rats. A similar system of two racks of five electrodes each is used to expose as many as 450 mice to fields at a maximum strength of 150 kV/m while sham exposing an equal number. Measurements of the electric field revealed an overall uniformity within 4% over the area to be occupied by experimental animals. The field inside a Lexan cage was reduced by about 3%. No corona-discharge was detected. Measurements of ozone concentration in the rat and mouse exposure systems showed no difference from background levels. Harmonic distortion was eliminated by damping and filtering the high-voltage supply. Animals housed in close proximity were partially shielded from the electric field; the total body current in a rat model was reduced by 35 ± 5% when rats were placed in adjacent cages.

6277 SOME THEORETICAL ASPECTS OF THE INTERACTION BETWEEN ELECTRICALLY EXCITABLE CELLS AND MAGNETIC FIELDS (MEETING ABSTRACT).
(Eng.) Jakobsson, E. (Dept. Physiology and Biophysics, Univ. Illinois, Urbana, IL 61801). *Biophys J* 25(2, part 2): 158a; 1979. (0 refs)

The problems associated with calculating magnetic fields produced by electrical activity were investigated and the effects on electrical activity of externally applied magnetic fields were calculated. Large magnetic forces were induced in nominally voltage-clamped membranes when the electric field was changing very rapidly, such as during the (almost) instantaneous step from one voltage to another during voltage clamp experiments. Possible effects of these forces on the results of voltage-clamp experiments are discussed.

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