reduced with 100 mmolar dithionite initially gave almost no field effect. When *o*-phenanthroline was added, the triplet yield in zero-field remained the same, but field effect became much stronger (up to 15%). It is concluded that the magnetic field effect is critically dependent on the value of the exchange parameter that measures the exchange interaction between members of the radical pair P^+I^- (P is the primary donor and I the first identifiable acceptor).

5110 LOSS OF VIABILITY OF PEAS CAUSED BY MICROWAVE HEATING. *(Eng.)* Schrader, D. H. (Electrical Engineering Dept., Washington State Univ., Pullman, WA); Patel, B. M. *Trans ASAE* 20(2): 354-359; 1977. (18 refs)

Loss of pea seed *(Pisum sativum)* viability due to short-term thermal heating or microwave exposure (916 MHz at power levels up to 20 kW) was investigated. Temperatures and exposure times for 50% survival after microwave heating were 73 C and 3,600 sec, 81 C and 1,000 sec, 89 C and 1,000 sec, 97 C and 27-50 sec, 107 C and 13-25 sec, 113 C and 5-10 sec, and 106 C and 4-8 sec. For thermal heating, the temperatures and exposure times for 50% survival were 54 C and 4.73 wk, 58.9 C and 6 days, 69.5 C and 36 hr, 70 C and 35.6 hr, 73.5 C and 9.5 hr, 79 C and 80.5 min, 79.5 C and 3,600 sec, and 90 C and 280 sec. A statistical analysis of these data indicates that any extra-thermal effect due to the microwave exposure was less than the variability of the temperature measurements that were performed calorimetrically and by infrared radiation monitoring.

5111 STUDIES ON THE HEMATOLOGIC EFFECTS OF LONG-TERM, LOW-DOSE MICROWAVE EXPOSURE. *(Eng.)* Djordjevic, Z. (Inst. Aviation Medicine-Zemun, Yugoslavia); Lazarevic, N.; Djokovic, V. *Aviat Space Environ Med* 48(6): 516-618; 1977. (17 refs)

Hematologic and morphologic studies on Wistar rats exposed to 2,400 MHz continuous microwave radiation at a mean power density of 5 mW/cm^2 were conducted. The rats were irradiated for 1 hr/day for 90 consecutive days. No significant differences in hematocrit, mean cell volume, hemoglobin, total leukocyte and erythrocyte counts, neutrophilic leucocytes, and lymphocytes were observed between test rats and control rats before, during, and after irradiation. Although moderate leukocytosis was observed during the experimental period in irradiated rats, similar alterations in the number of leukocytes in peripheral blood were observed in control animals. Thus, the leukocyte shifts observed during the experiment do not appear to be the result of microwave irradiation. Morphologic studies did not reveal any evident changes in the spleen, liver, heart, brain, or testicles.

5112 ELECTRICAL BONE-GROWTH STIMULATION IN AN EXPERIMENTAL MODEL OF DELAYED UNION. *(Eng.)* Paterson, D. C. (Adelaide Children's Hosp., Adelaide, Australia); Carter, R. F.; Maxwell, G. M.; Hillier, T. M.; Ludbrook, J.; Savage, J. P. *Lancet* 1(8025): 1278-1281; 1977. (25 refs)

The effects of direct current stimulation on bone healing in an experimental model involving delayed bone healing of the tibia in adult dogs were assessed in a double-blind trial. A commercial bone growth stimulator was used to supply a constant sum current of 20 μA through one stainless-steel cathodic electrode; there were two platinum anodes carrying approximately half of the sum current. The electrodes were passed retrogradely into the defect area where the anodes were inserted into the medullary cavity at a point 1.5 cm above and below the defect; the cathode was made into a helix and inserted into the defect area. Two groups of 24 dogs each with delayed bone healing for 4 wk were attached to electrodes, which were connected to either active or inactive stimulators. Osteogenesis in dogs with active electrodes was superior to that in dogs with inactive electrodes when evaluated by the criteria of gamma imaging ($P = 0.05$) and clinical union ($P = 0.05$). Using these two criteria plus the additional criterion of histologic appearance, healing in dogs with active electrodes was found to be superior to that in dogs with inactive electrodes at the 1% level of significance. Histologic assessment revealed normal bone healing by endomembranous and endochondral ossification. Inflammatory changes were insignificant and did not inhibit osteogenesis. There was no evidence of dysplastic or neoplastic changes in dogs receiving direct current stimulation. Therefore, electrical stimulation can significantly accelerate bone healing in an experimental situation analogous with delayed bone union in man.

5113 HEMOLYSIS OF HUMAN ERYTHROCYTES BY A TRANSIENT ELECTRIC FIELD. *(Eng.)* Kinosita, K. (Dept. Physiological Chemistry, Johns Hopkins Univ. Sch. Medicine, Baltimore, MD 21205); Tsong, T. Y. *Proc Natl Acad Sci USA* 74(5): 1923-1927; 1977. (20 refs)

The exposure of human erythrocytes to a high voltage pulse of a few kV/cm under isotonic conditions led to total hemolysis of the red blood cells. Hemolysis was due to a field-induced transmembrane potential; neither the effect of current nor the extent of the rapid Joule heating to the suspending medium showed a direct correlation with the observed hemolysis. High ionic strength in the pulsation medium markedly reduced the hemolysis rate. When erythrocytes were treated with a 20 μsec pulse at 3.7 kV/cm and then transferred into an isotonic sodium-chloride solution, 50% hemolysis was attained at 0.2 min, 0.6 min, 13 min, and 4 hr, respectively, for pulsation media containing 3, 10, 30, and 100% isotonic sodium chloride. Voltage pulsation of the erythrocyte suspension was capable of inducing a transmembrane potential across the cell membrane, which at a critical point either opened up or created pores in the erythrocytes. In isotonic saline the pores were small and allowed passage of potassium and sodium ions but not sucrose and hemoglobin (Hb) molecules. In contrast, larger pores, which admitted

sucrose but not Hb were obtained by pulsation in 30% sodium chloride-70% sucrose isotonic mixture. Kinetic measurements indicated that the hemolysis of the erythrocytes followed a stepwise mechanism: leakage of ions led to an osmotic imbalance, which in turn caused a colloidal hemolysis of the erythrocytes.

5114 SENSITIVITY OF THE HOMING PIGEON TO AN EARTH-STRENGTH MAGNETIC FIELD. *(Eng.)* Bookman, M. A. (Dept. Psychology, Massachusetts Inst. Technology, Cambridge, MA 02139). *Nature* 267(5609): 340-342; 1977. (25 refs)

A flight tunnel constructed within a controlled magnetic environment was used to train three pairs of homing pigeons (*Columbia livia*) to discriminate between an earth-strength induced magnetic field (0.5 G) and a 0.02 G background field. The pigeons were allowed to travel the length of the tunnel and were trained to enter the correct feeding box associated with each magnetic field condition. Two basic patterns of response were observed during adaptation and training of the pigeons. After landing, the birds would either walk the length of the tunnel or engage in a period of spontaneous flutter activity before entering a feeding box. Flutter consisted of sustained hovering, jumping, rapid turning, and short flights. The data showed a statistically significant discrimination between the two magnetic field conditions that was even more apparent when the trials were separated according to flutter activity. In all cases, 'with flutter' trials were statistically nonrandom, while the 'no flutter' trials were random. Homing pigeons, therefore, appear to have a magnetic field sensitivity which is somehow associated with flutter activity.

5115 FLUOROSCOPE-GENERATED ELECTROMAGNETIC INTERFERENCE IN AN EXTERNAL DEMAND PACEMAKER. REPORT OF A CASE. *(Eng.)* Leeds, C. J. (Cardiology Dept., USPHS Hosp., Staten Island, NY 10304); Akhtar, M.; Damato, A. N. *Circulation* 55(3): 548-550; 1977. (8 refs)

Electromagnetic interference from a faulty fluoroscopy unit caused inhibition and resetting of the demand circuitry of a ventricular-inhibited temporary external pacemaker in a 70-yr-old man undergoing surgical implantation of a permanent bipolar pacemaker generator and lead. The external pacemaker was set at an automatic pacing interval of 850 msec with the sensitivity control at maximum. The stimulus output was adjusted to 2 mA, 1.4 mA greater than the ventricular pacing threshold. The fluoroscopy unit, which was used to observe the cardiac silhouette, was in the vicinity of the external temporary transvenous pacing equipment. The arrhythmia was due to oversensing of waveforms (modulated to simulate myocardial potentials) that were emitted by the fluoroscopy unit. Examination of the fluoroscopic unit revealed a faulty relay that interfered with the normal flux density of the transformer, causing a build-up during viewing and a release of excess transient current across the circuit upon deactivation. Replacement of the relay and the addition of a resistor and capacitor to the circuit eliminated the offending electromagnetic transmission.

5116 NONMETALLIC ELECTRODE SYSTEM FOR RECORDING EEG AND ECG IN ELECTROMAGNETIC FIELDS. *(Eng.)* Flanigan, W. F. (Biomedical Group, Undersea Sciences Dept., Naval Undersea Center, San Diego, CA 92132); Bowman, R. R.; Lowell, W. R. *Phys Behav* 18(3): 531-533; 1977. (5 refs)

A nonmetallic electrode/lead system for recording biopotentials in the presence of electromagnetic fields is described which minimizes field enhancement artifacts associated with metal and other electrode systems. The electrode is a 10-cm strip of 4 siemens (S)/m carbon-loaded teflon (CLT), which is 1 mm wide and 0.25 mm thick. The lead is a strip of 72 S/m CLT of identical width and thickness. In comparison with thin copper electrodes, which can have field enhancements on the order of 10^7, the electrode material used in the above system produces only a marginal field enhancement of 1.3 at 960 MHz and even causes a field reduction of 0.6 at a frequency of 2,450 MHz. By keeping the separation between the two electrodes and the two leads to a mininum, noise is effectively eliminated in the system when it is placed perpendicular to the electric field component of incident electromagnetic fields at power levels up to 100 mW/cm^2. The electrode system has been used to record brain wave and heart rate activity in both acutely and chronically implanted chelonians (turtles and tortoises). Electrode tips were inserted up to 2-3 mm between dura and skull and between underlying soft tissue and the upper shell for monitoring electroencephalograms and electrocardiograms, respectively. Recordings compared favorably with those obtained from animals chronically implanted with metal electrodes and connecting wires.

5117 THE BIOLOGICAL EFFECT OF THE ELECTRIC FIELDS OF HIGH-TENSION LINES ON MAN. *(Ger.)* Stimmer, H. (Vorstand des Instituts fuer Elektrische, Anlagen und Hochspannungstechnik der Technischen Universitaet Wien, Gusshausstrasse 25, A-1040 Wien, Austria). *Oesterr Z Elektriz* 30(3): 86-89; 1977.

A survey of the effects of the electrical fields in high-tension lines on the human body is presented. A 1972 Soviet report pointed out that headache, nausea, and vertigo were observed in people working in new 500 kV high-tension switchgear plants after exposure of several months. Subsequently, a group of 250 persons employed in high-tension plants with longer and more frequent exposure to electric fields of up to 30 kV/m was investigated. The workers revealed breakdown symptoms in the central nervous system, disorders of the cardiovascular system, morphologic changes in the blood, and reduced sexual

potency in young men. Similar studies in various European countries involving groups of people exposed to electric fields of 20 kV/m, 200-400 kV did not show any significant changes in vital signs. A Spanish study reports that three workers who were employed for more than 10 yr at a 400 kV-plant, displayed vertigo, loss of appetite, insomnia, retching spells, and visual disturbances. These symptoms disappeared after cessation of field effect. Evaluation and comparison of the variable results were difficult because potential changes were not limited to the pathologic range alone. The effects never exceeded standard borderline values and could have been due to any number of everyday environmental causes.

5118 ARTERIAL PRESSURE UNDER THE INFLUENCE OF LOW-INTENSITY MICROWAVES AND HIGH TEMPERATURE. *(Rus.)* Sadchikova, M. N. (Inst. Labor Hygiene and Occupational Diseases, Acad. Med., Moscow USSR); Nikonova, K. V.; Denisova, E. A.; Snegova, G. V.; Lvovskaya, E. N.; Soldatova, V. A. *Gig Tr Prof Zabol* 2: 17-21; 1977. (8 refs)

The vascular tone of 885 individuals occupationally exposed to low-intensity microwave radiation and high temperature was investigated. Of the 885 people, 275 men and 78 women were in contact with microwave radiation sources, and 532 (411 males, 121 females) served as controls. The group under investigation was subdivided according to working conditions. Group I consisted of 182 men (up to 40 yr old-73.1%) manufacturing radiolocation equipment and UHF units with length of service of up to 10 yr. They were periodically exposed to microwave radiation ranging from a few to hundreds of $\mu W/cm^2$ at 2-3 hr/day. They also worked at high temperatures (37-39 C). Group II consisted of 93 men (up to 40 yr old-69.9%) and 78 women (up to 40 yr old-52.6%) working with radio relay control equipment and control-adjustment of electronic instruments, who received about 10 $\mu W/cm^2$. Service records ranged from 3-20 yr. Clinical examination showed the majority of all groups to be healthy; however, hypertension was noted in men exposed for 5 yr or longer to microwave radiation of hundreds of $\mu W/cm^2$ and high temperature and in women with 10-20 yr of work exposure to microwave radiation of up to 10 $\mu W/cm^2$.

5119 BIOLOGICAL EFFECTS OF MICROWAVE AND RADIOFREQUENCY RADIATION. *(Eng.)* Cleary, S. F. (Dept. Biophysics, Virginia Commonwealth Univ., Richmond, VA). *CRC Crit Rev Environ Control* 7(2): 121-166; 1977. (100 refs)

Studies conducted over the past 6 yr on the biologic effects of microwave (30-300 MHz) and radiofrequency (RF: 30-300 kHz) radiation are reviewed with particular emphasis on the existence and/or significance of low-intensity (less than 10 mW/cm^2) effects. Hematopoietic effects such as changes in leukocyte, lymphocyte, and neutrophile count; altered mitotic activity in erythroblasts, bone marrow cells, and lymphatic cells; and changes in blood urea nitrogen and serum glucose have been observed in experimental animals exposed to frequencies ranging from 1.28-24 GHz at power intensities of 0.5-165 mW/cm^2. Reported alterations in thyroid function associated with occupational microwave exposure suggest that the neuroendocrine system is sensitive to microwave and RF fields at intensities that can induce low levels of tissue heating. Microwave or RF exposure may also alter the susceptibility to stress of insult by viral or bacterial pathogens. For example, the granulopoietic reaction to staphylococcal insult in rabbits exposed for 6 hr/day to 3-GHz microwaves (3 mW/cm^2 intensity) was significantly different from that of unirradiated rabbits. The susceptibility of mice to the effects of certain drugs such as, pentetrazol, has been altered by exposure to 3-GHz pulse-modulated microwaves at an average power of 5 mW/cm^2. Although the effects of long-term low intensity occupational microwave exposure on the human lens are unclear, increases in the rate of lens aging have been reported in connection with such exposures. Experimental thresholds for microwave pulse-evoked auditory sensation have been related to the incident pulse energy, with values of 20 J/cm^2 for cats and 40 J/cm^2 for humans at pulse durations of 30 μsec or less. Additional research is necessary before any definite conclusions may be drawn about the effects of low-intensity microwave or RF exposure on mammalian reproduction and development. Although significant differences in the results of studies on microwave- or RF-induced central nervous system effects exist, low intensity fields at times induce detectable changes in nerve structure, electrophysiology, or behavior. Significant alterations in the behavior of albino rats trained to respond on multiple reinforcement schedules were induced by both S- and X-band irradiations at intensities of 5 mW/cm^2 or greater.

5120 TUMOR CURE AND CELL SURVIVAL AFTER LOCALIZED RADIOFREQUENCY HEATING. *(Eng.)* Marmor, J. B. (Div. Radiology, Stanford Univ. Sch. Medicine, Stanford, CA 94305); Hahn, N.; Hahn, G. M. *Cancer Res* 37(3): 879-883; 1977. (15 refs)

A 13.56 MHz unmodulated electromagnetic field from a radiofrequency generator was used to locally heat EMT-6 mammary sarcomas and KHJJ carcinomas, which were intradermally implanted (10^5 viable tumor cells) in BALB/cKa mice. Temperature profiles indicated uniform temperature distribution throughout the tumor volume with no systemic hyperthermia. Typical initial incident power levels were 0.9 W/cm^2, and average maintenance powers were about 0.6 W/cm^2. Host body temperature rose slowly but did not exceed 37 C. Both tumors were highly sensitive to cure by radiofrequency heating, with the cure rate being a function of temperature and exposure duration. Exposures of 20 min or longer at 44 C were sufficient to cure all mice with EMT-6 sarcomas. Approximately 50% cure rates were achieved with 5 min of exposure at 44 C with 10-min exposure at 43.5 C and with 30-min exposure at 43 C. The KHJJ tumor was more resistant to cure than the EMT-6 tumor. At 43.5 and 44 C, 20-min exposures were required to produce

a 50% cure rate; 100% cure rates were not achieved. Tumor cell survival studies on EMT-6 tumors treated in situ revealed that cell inactivation by radio-frequency heating was similar to that for hot water bath heating. However, direct cell killing cannot account for the observed cures, and it is postulated that an additional delayed mechanism involving either intratumor or host response must play a major role in tumor eradication.

5121 A MULTIPLE-ANIMAL ARRAY FOR EQUAL POWER DENSITY MICROWAVE IRRADIATION. *(Eng.)* Oliva, S. A. (Armed Forces Radiobiology Res. Inst., Defense Nuclear Agency, Bethesda, MD 20014); Catravas, G. N. *IEEE Trans Microwave Theory Techniques* 25(5): 433-436; 1977. (7 refs)

A Styrofoam and Plexiglas exposure array, which permits the simultaneous irradiation of multiple animals at a uniform average microwave power density, is described. The array consists of microwave transparent cages positioned in accordance with the natural characteristics of the microwave field and separated sufficiently to insure minimum interaction between animals due to microwave reflection. Experiments in which the array was tested in an anechoic chamber at a frequency of 2,450 MHz using an isotropic field probe, which was placed in a given cage concurrently with the placement of rats in all other cages, revealed that the average power density in any cage varied by no more than ± 5% from the composite average of all cages. Differences in perturbations between cages closest to the microwave antenna and those farthest from the antenna may be compensated for by rotating the animals through all cages on a day-to-day basis.

5122 SINGLE AUDITORY UNIT RESPONSES TO WEAK, PULSED MICROWAVE RADIATION. *(Eng.)* Lebovitz, R. M. (Dept. Physiology, Univ. Texas Health Science Center at Dallas, Dallas, TX 75235); Seaman, R. L. *Brain Res* 126(2): 370-375; 1977. (19 refs)

Extracellular single auditory unit responses were recorded from the proximal portion of the eighth nerve of cats exposed to pulsed microwave radiation (915 MHz) with an average absorved power density of 1 mW/g or less, a pulse repetition rate of 10/sec or less, and pulse width ranging from 25-300 μsec. The microwave energy was applied via a pulse-modulated source connected to a waveguide applicator located 2-5 cm from the dorsolateral side of the cat's head. Among 100 auditory units studied in seven cats, 32 were found to be responsive to both acoustic clicks and to pulsed microwave stimuli. The response amplitude varied directly with the microwave pulse amplitude at any given microwave pulse width. The microwave poststimulus time histograms (PSTH) of a given unit generally showed the same qualitative interval distribution for pulse energy densities ranging from threshold (less than 4 μJ/g/pulse) to about 40 μJ/g. The microwave-induced responses appeared to be shaped by the peripheral auditory apparatus based on the following observations: there was a 2-5 msec latency for the observed unitary response to the pulsed microwave radiation; the microwave PSTH was generally of the same form as the acoustic PSTH; and the single unit response appeared to be a nonmonotonic function of pulse width. The most satisfactory current hypothesis for the observed auditory response is that the incident microwave pulse sets up a thermo-acoustic wave in the head that mechanically stimulates the inner ear via bone conduction.

5123 THE LEVELS OF GABA IN MOUSE BRAIN FOLLOWING TISSUE INACTIVATION BY MICROWAVE IRRADIATION. *(Eng.)* Knieriem, K. M. (State Lab. Hygiene, Univ. Wisconsin, Center Health Sciences, Madison, WI 53706); Medina, M. A.; Stavinoha, W. B. *J Neurochem* 28(4): 885-886; 1977. (20 refs)

Postmortem gamma-aminobutyric acid (GABA) levels were determined in mouse brain tissue after inactivation by microwave (2,450 MHz) radiation. Preliminary experiments indicated that 200 msec was adequate time to stabilize postmortem brain GABA levels. The concentration of GABA in the brain of mice treated with 6 kW of microwave radiation for 200 msec was comparable to that previously observed in mice and rats after rapid freezing. When the brain was removed and allowed to remain at room temperature for 30 min prior to homogenization, GABA levels increased from 2.27 ± 0.16 μmol/g tissue at 0 time (within 2 min of death) to 2.37 ± 0.07 μmol/g after 30 min in decapitated mouse brain as compared with 0 and 30-min values of 1.99 ± 0.02 and 1.89 ± 0.05 μmol/g, respectively, for microwave-treated mice. Therefore, exposure to 200 msec of microwave radiation effectively prevented postmortem elevation of brain GABA. The lowest GABA level in microwave-treated mice were found in the cerebellum (0.88 ± 0.08 μmol/g) and the highest in the hypothalamus (3.55 ± 0.08 μmol/g).

5124 THERMAL RESPONSES TO HIGH-FREQUENCY ELECTROMAGNETIC RADIATION FIELDS. *(Eng.)* Frazer, J. W.; Merritt, J. H., Allen, S. J.; Hartzell, R. H.; Ratliff, J. A.; Chamness, A. F.; Detwiler, R. E.; McLellan, T. (USAFSAM (RAP), Aerospace Medical Div. (ARSC), Brooks Air Force Base, TX 78235). 19 pp.; 1976. [available through National Technical Information Services, Springfield, VA 22161, Document No. AD A032179]. (17 refs)

Male rhesus monkeys were exposed in a coaxial transmission line to 26 MHz continuous wave radiation for 6 hr (interrupted every 30 min for rectal temperature measurement) at field densities of 500, 750, and 1,000 mW/cm^2. An immediate rise in skin and rectal temperature with subsequent cooling was observed. Rectal temperature reached an equilibrium after about 1.5 hr of exposure, and this equilibrium was maintained throughout the remainder of the exposure period. At the highest exposure (1,000 mW/cm^2), the rectal temperature initially rose from 38.1 to 39.4 C and reached an equilibrium at 38.8 C.

Skin temperature rose from 36.1 to 38.6 C during the first 30 min of exposure, and the final reading was about 0.1 C above baseline. Uninterrupted exposure to 500 and 750 mW/cm^2 resulted in rectal temperature increases of 1 C and 1.7 C, respectively. At 500 mW/cm^2, the skin temperature initially increased and then reached its initial value after 6 hr. At 750 mW/cm^2, the skin temperature tended upward throughout the run and was about 2.8 C higher after 6 hr than the initial reading. Rectal cooling rates at 500, 750 and 1,000 mW/cm^2 were 0.36, 2.64, and 3.54 C/hr, respectively, and the corresponding skin cooling rates were 1.74, 2.46, and 1.75 C/hr. Such cooling rates were sufficient to bring the core and skin temperature to normal values in an hour or less, indicating that the thermoregulatory mechanisms were not impaired even at 1,000 mW/cm^2 and that the monkeys were able to dissipate the heat load following cessation of radiation. The 1,000 mW/cm^2 field applied to the primates is approximately equivalent to 400 mW/cm^2 in man.

5125 SOURCES AND BIOLOGICAL EFFECTS OF NONIONIZING ELECTROMAGNETIC RADIATION. *(Eng.)* Sosnicky, A. P. (Master's Thesis, Naval Postgraduate Sch., Monterey, CA 93940). 73 pp.; 1976. [available through National Technical Information Services, Springfield, VA 22161, Document No. AD A032367]. (46 refs)

The uses, characteristics, and possible hazards of radiation emitted by communications and radar equipment are described, and a review of Soviet and Western studies on the biological effects of nonionizing electromagnetic radiation is presented. Soviet studies of nonthermal effects indicate that frequencies ranging from 30-300,000 MHz at both thermogenic (greater than 10 mW/cm^2) and nonthermogenic intensities are capable of producing subjective symptoms in man, which include weakness, dizziness, depression, mental function impairment, sex drive inhibition, and gastrointestinal complaints. General clinical syndromes associated with microwave radiation exposure according to the Soviets include the asthenic syndrome, autonomic dystonia, and the diencephalic syndrome. Soviet studies at extremely low frequencies (50 Hz) and at fields strengths ranging from 15-420 mWb/m^2 indicate that such exposures are capable of producing nervous system changes associated with autonomic functions. Generally, the syndromes and organ responses described in Soviet literature have not been confirmed by Western studies, which stress the thermal effects of microwave exposure (potential damage to the eye lens and the testes). The Soviet maximum permissible microwave dose for human exposure is 0.1 mW/cm^2 are compared with the United States standard of 10 mW/cm^2.

5126 GEOMAGNETIC DISTURBANCE AND THE ORIENTATION OF NOCTURNALLY MIGRATING BIRDS. *(Eng.)* Moore, F. R. (Dept. Zoology, Clemson Univ., SC 29631). *Science* 196(4290): 682-684; 1977. (27 refs)

Direct visual evidence that the orientation of free-flying nocturnal migrants is affected by natural fluctuations in the geomagnetic field is presented. Data obtained from ceilometer watches and moon watches during the spring and fall seasons revealed a significant relationship between the K index, a measure of superimposed geomagnetic disturbance, and the angular deviation in the flight direction of free-flying passerine migrants. Variables reflecting geomagnetic activity before and after a watch were unimportant in both seasons, suggesting that any response to geomagnetic disturbance is immediate (within 3 hr). It is not known whether the magnetic disturbances act directly or indirectly on the avian orientation system.

5127 MICROWAVE ALTERATION OF THE BLOOD-BRAIN BARRIER SYSTEM OF RATS. *(Eng.)* Oscar, K. J. (U.S. Army Mobility Equipment R & D Command, Fort Belvoir, VA 22060); Hawkins, T. D. *Brain Res* 126(2): 281-293; 1977. (34 refs)

The effect of microwave exposure on the uptake of saccharides in the brain of male Wistar rats were studied. A single 20-min exposure to either pulsed (square wave) or continuous wave (CW) 1.3 GHz microwave energy induced an increase in the uptake of radiocarbon-labeled D-mannitol at average power densities of less than 3.0 mW/cm^2. The permeability change was greatest in the medulla, followed in decreasing order by the cerebellum and hypothalamus, with small or negligible changes in the hippocampus and cortex. Although permeability increases were observed for mannitol as well as for inulin, they were *not observed for dextran.* In general, mannitol uptake increased with increasing power density for both pulsed and CW microwave signals up to 0.5-2.0 mW/cm^2 where the brain uptake index (BUI) started to level off and then decrease. Increased permeability was observed both immediately and 4 hr after microwave exposure but not 24 hr after exposure. Pulsed energy with a high peak power, large pulse widths, and few pulses/sec affected mannitol uptake at an average power density of only 0.03 mW/cm^2; whereas, it took a CW energy of approximately 0.3 mW/cm^2 to cause the same magnitude of change. BUI measurements for pulse rates ranging from 5-1,000 pulses/sec, pulse widths ranging from 0.5-20.0 μsec, and peak power densities of 60-1,600 mW/cm^2 suggested that the BUI is a direct function of all three of the above parameters. The effect of peak power on mannitol seemed to be greater than the effect of pulse width, and both appeared to have a greater effect on permeability than the pulse rate. Microwaves appear to induce temporary changes in the permeability of the blood-brain system of rats for small molecular weight saccharides.

5128 A MICROWAVE IRRADIATION CHAMBER FOR SCIENTIFIC STUDIES ON AGRICULTURAL PRODUCTS. *(Eng.)* Olsen, R. G. (Dept. Electrical Engineering, Washington State Univ., Pullman, WA 99163); Geithman, G. A.; Schrader, D. H. *IEEE Trans Microwave Theory Techniques* 25(5): 428-433; 1977. (22 refs)

A waveguide microwave irradiation chamber in which homogeneous agricultural materials with simple geometrics can be heated uniformly in a controlled manner is described. A 25-kW microwave source (915 MHz) was coupled to a WR-975 waveguide and terminated in a water load. The material to be irradiated was formed into a post and placed in the center of the waveguide. Thermocouple measurements in plaster of Paris posts indicated uniform heating of the sample. A system for conducting irradiation tests on soils was designed that overcomes nonuniform distribution of temperature during the cooling period of the experiment. The soil was placed inside a cylindrical container constructed of lossless dielectric. A hole was machined in the waveguide below the soil and was covered by a thin piece of aluminum foil during irradiation. A pipe was used to connect the hole in the waveguide to a jar of cold water and a vacuum chamber, which was sealed during irradiation. Upon cessation of irradiation, the vacuum chamber was opened and the soil quickly drawn into the cold water, dispersed, and cooled quickly. Thus differences in temperature in the sample existed for such a short time that they were negligible.

5129 TERATOGENIC EFFECTS ON RAT OFFSPRING OF NON-THERMAL CHRONIC PRENATAL MICROWAVE IRRADIATION (MEETING ABSTRACT). *(Eng.)* Jensh, R. P. (Dept. Anatomy, Thomas Jefferson University, Philadelphia, PA); Ludlow, J.; Weinberg, I.; Vogel, W. H.; Rudder, T.; Brent, R. L. *Teratology* 15(2): 14A; 1977.

Ten pregnant rats were exposed in an anechoic chamber to 10 mW/cm^2 of microwave radiation at 915 MHz for 8 hr daily throughout gestation to determine the effect on the offspring. Total exposure time was 110 hr. It had been previously determined that dosage levels up to 10 mW/cm^2 were non-thermal; i.e., no increase in total body temperature was observed as measured by rectal thermistor probe. Control animals were placed in the chamber for similar periods of time. All animals were killed on the 22nd day of gestation. The fetuses were removed, weighed, and fixed after recording position and resorptions. There were no significant differences noted among the control groups, nor between the control and irradiated animals for the following parameters: embryonic or fetal death, abnormality, term fetal weight, term placental weight, term litter size, fetal sex ratio, and maternal weight and weight gain. These results indicate that exposure to a nonthermal level of microwave irradiation at 915 MHz throughout rat gestation does not adversely affect the offspring.

5130 A MODIFIED RADIOMETER FOR TEMPERATURE AND MICROWAVE PROPERTIES MEASUREMENTS OF BIOLOGICAL SUBSTANCES (MEETING ABSTRACT). *(Eng.)* Mamouni, A.; Bliot, F.; Leroy, Y.; Moschetto, Y. *In: Book of Abstracts of Seventh European Microwave Conference: The International Conference and Exhibition Designed for the Microwave Community. 5th-8th September, 1977, Copenhagen, Denmark.* p. 71; 1977. (0 refs)

The use of radiometers for biomedical applications needs a coherent understanding of thermal signals emitted by the tissues. In the conventional method, the detected signal generally depends on both the temperature of the material and the reflection coefficient. These parameters cannot be separated. In this study an alternative method was employed that allowed either a direct measurement of the temperature or a simultaneous determination of the reflection coefficient and the temperature. Measurements on organic liquids were performed using an X-band radiometer with a FET microwave amplifier. Possibilities of applications for biomedical topics are presented.

5131 MEASUREMENT OF ATP, ADP AND AMP IN MOUSE LUNG AFTER INACTIVATION BY MICROWAVE RADIATION (ABSTRACT). *(Eng.)* Hawkins, S. F. (Univ. Texas Health Science Center at San Antonio, Dept. Pharmacology, San Antonio, TX 78284; Medina, M. A.; Stavinoha, W. B. *Fed Proc* 36(3): 480; 1977. (0 refs)

Levels of adenosine triphosphate (ATP), adenosine diphosphate (ADP), and adenosine monophosphate (AMP) in mouse lung were measured after the lungs were inactivated in vivo by 6 kW microwave irradiation (MWR) for 440 msec. In another group the lungs were removed and homogenized in 0.4 N $HCLO_4$ within 2 min after sacrifice by decapitation. In a third group the lungs were inactivated by freeze clamping. There were no significant differences in the concentration of any of the metabolites regardless of the method of tissue inactivation. The absence of a decrease in the levels of these metabolites in the decapitated group was not anticipated because of the rapid postmortem decrease in these metabolites in other tissues. This may have been due to the presence of adequate postmortem Po_2 levels in the lungs. No ATPase activity was observed in the MWR tissue. Although rapid inactivation may not be an important factor in preventing postmortem changes of ATP, ADP, and AMP in lung, rapid irreversible inactivation produced by MWR would eliminate the possibility of postmortem changes in the levels of other labile lung metabolites.

5132 MAGNETIC ENHANCEMENT OF ELECTRON DOSE DISTRIBUTION IN A PHANTOM. *(Eng.)* Whitmire, D. P. (Dept. Physics, Univ. Southwestern Louisiana, Lafayette, LA 70501); Bernard, D. L.; Peterson, M. D.; Purdy, J. A. *Med Phys* 4(2): 127-131; 1977. (5 refs)

The effect of a 10-kG magnetic field on the dose distribution of electrons in a polystyrene phantom was studied to determine if radiotherapeutic tumor-to-skin dose ratios can be improved. Isodensity plots and depth-dose curves were obtained for 22- and 28-mega electron volt (MeV) beams with and without the applied magnetic field. For the 28-MeV beam, the maximum dose (density) region was shifted to about 3 cm below the surface of the phantom as

compared with about 1 cm from the surface for magnet-off conditions. The absolute value of the measured maximum density was about 20% greater for the magnet-on data. In addition to reducing surface dose, the magnetic field also produced a rapid falloff in dose past the maximum-density region. A comparison of the 28-MeV magnet-on case with the optimum magnet-off energy for treating a given tumor was made, and at 12 MeV the magnet-off dose distribution was found to fall off about as fast as the 28-MeV magnet-on distribution for a 10-kG field. In addition to improving the tumor-to-skin dose ratio, the magnetic field is also capable of shaping the distribution either symmetrically or asymmetrically, allowing to some extent for the generation of an optimum distribution for a given tumor volume. Symmetrical distribution is produced by reversing the magnet's polarity halfway through the administered dose, and the shape of this flared distribution depends on the axis chosen for the reversed dose. By shielding the fringe fields and holding the beam axis constant for both polarity cycles, good symmetrical dose distributions have been obtained for energies as low as 10 MeV, with the magnetic Bragg peak occurring at a greater depth than the magnet-off 80% depth for energies less than or equal to 25 MeV. Magnetic surface doses obtained with an 18.2-kG field are approximately half the magnet-off surface dose of the same energy.

5133 BIOLOGICAL EFFECTS BY MICROWAVES (MEETING ABSTRACT). *(Eng.)* Berteaud, A. J. *In: Book of Abstracts of Seventh European Microwave Conference: The International Conference and Exhibition Designed for the Microwave Community. 5th-8th September, 1977, Copenhagen, Denmark.* p. 64; 1977. (0 refs)

The biologic effects of microwave radiation are reviewed. Topics covered include: protection conditions and safety standards; the effects of low and high power density microwave radiation on unicellular and pluricellular organisms; the induction of hyperthermia, with emphasis on its role in cancer therapy; and the nonthermal effects of microwaves.

5134 DESIGN AND APPLICATION OF SPECIAL MICROWAVE INTERFEROMETERS FOR NON-INVASIVE STUDIES OF BIOLOGICAL EFFECTS (MEETING ABSTRACT). *(Eng.)* Griffen, D. W. *In: Book of Abstracts of Seventh European Microwave Conference: The International Conference and Exhibition Designed for the Microwave Community. 5th-8th September, 1977, Copenhagen, Denmark.* p. 70; 1977. (0 refs)

Microwave interferometers were designed to make noncontact measurement of the movements associated with various physiologic functions such as respiration, pulse, muscle action, reflexes, and involuntary tremors. For each interferometer the factors affecting resolution across a large moving surface, sensitivity to small amplitude displacement, and maintenance of calibration were studied and accurate direct measurement of surface displacement was achieved with very low incident microwave power levels. Interferometers based on three port circulators were most sensitive but those based on magic tee hybrids were easier to operate. Movement of the chest, hands, legs, and eyeball has been studied and potential for accurate correlation with electroencephalogram, electrocardiogram, or electromyogram records was demonstrated.

5135 MILLIMETER WAVE THERMOGRAPH AS SUBCUTANEOUS INDICATOR OF JOINT INFLAMMATION (MEETING ABSTRACT). *(Eng.)* Edrich, J.; Smyth, C. J. *In: Book of Abstracts of Seventh European Microwave Conference: The International Conference and Exhibition Designed for the Microwave Community. 5th-8th September, 1977, Copenhagen, Denmark.* p. 71; 1977. (0 refs)

A technique for remote noninvasive mapping of temperature elevations of human joints that uses the mm wave radiation emitted by the human body was evaluated. A solid state switched scanner for 68 GHz, which overcomes the depth limitations of conventional infrared thermographs and can measure to subcutaneous depths of several mm with a temperature resolution of 0.25 C was employed. Measurements on rheumatoid arthritic knee joints showed little correlation with simultaneously measured skin temperatures. Significant long-term thermographic changes induced by steroid injection indicate a potential for objective patient monitoring and development of new treatment methods.

5136 INFLUENCE OF ALTERNATING ELECTRIC FIELDS OF TECHNICAL FREQUENCY ON CHICKEN EMBRYOS (MEETING ABSTRACT). *(Eng.)* Wittke, G. (Dept. Veterinary Physiology, Free Univ. Berlin, Koserstr. 20, D-1000 Berlin 33, Germany); Bootz, A.; Bayer, A.; Brinkman, J. *Pfluegers Arch* 368(Suppl.): R27; 1977. (0 refs)

The effects of alternating electric fields on chicken embryos were studied. Fifty or 100 eggs from SPF hens were put into the upper part of an incubator (controls). Simultaneously, another group of the same size was placed beneath in a layer vertically penetrated by alternating electric fields (50 Hz) with intensities of 1, 1.5, or 5 kV/m (related to the homogenic field). Throughout the brooding period the usual precautions as to temperature, humidity, and periodic turning of the eggs were observed. After hatching, the chickens were held below an infrared lamp for 3 wk in a thermoneutral environment. Body weights were determined daily. The hatching rates of the fertilized eggs on the three increasing steps of field intensity were 88, 80, and 81%, respectively. The corresponding data in the control groups amounted to 80, 82, and 57%, respectively. The growth of chickens from eggs within and outside electric fields was identical. The grasp reflex was normal. These findings controdict the results of a previous study in which chickens exposed to electric fields during incubation exhibited malformations of feet and a high

mortality rate. It is hypothesized that the alterations noted in the earlier study were caused by factors other than electric fields.

5137 PGE_1-STIMULATION OF ADENYL CYCLASE IN THE BRAIN OF RATS EXPOSED TO LOW POWER DENSITY MICROWAVE RADIATION (MEETING ABSTRACT). *(Eng.)* Catravas, G. N. (Armed Forces Radiobiology Res. Inst., Defense Nuclear Agency, Bethesda, MD 20014); Katz, J. B.; Takenaga, J. *Radiat Res* 70(3): 691; 1977. (0 refs)

Groups of male Sprague-Dawley rats were exposed to continuous wave microwave radiation (2,450 MHz, 15 mW/cm^2) in an anechoic chamber. The animals were irradiated 8 hr/day for 5 wk between 0800 and 1600 hr. During exposure the animals were confined in styrofoam cages, the inner walls of which were coated with quinine to prevent the rats from chewing through the walls of the cages. Control animals, effectively protected from the microwave beam, were kept in the same exposure chamber under the same environmental conditions as the experimental animals. An increased sensitivity of brain adenyl cyclase to PGE_1 was observed with a shift of the dose/response curve to the left. This shift seemed to be more pronounced in irradiated animals sacrificed 8 hr postexposure than among those sacrificed immediately after removal from the exposure chamber. However, the maximal adenyl cyclase activity did not appear to be affected.

5138 THE ROLE OF RADIO SCIENCE IN INVESTIGATING ELECTROMAGNETIC BIOLOGICAL HAZARDS. *(Eng.)* Johnson, C. C. (Dept. Bioengineering, Univ. Utah, Salt Lake City, Utah 84112). *Radio Sci* 12(3): 349-354; 1977. (42 refs)

The involvement of the URSI in research concerning the possible human hazards of electromagnetic radiation is discussed. Particular areas of interest to the URSI include metrology for providing better electromagnetic field and absorbed power measurements in biological specimens and the application of field theory techniques to the determination of absorbed power in three-dimensional biologic models. Techniques that have been devised for the measurement of temperature and electromagnetic fields in tissue include an implantable probe with a very small thermistor and carbon-loaded Teflon lead wires, a liquid crystal fiber optic system, a combination of fiber optics with a Faraday-rotation optical crystal, and thermographic camera measurements using phantom materials. Theoretic dosimetry calculations are being used to predict absorbed electromagnetic power in tissues. Multi-layer analyses have resulted in significant understanding of the microwave absorption properties of tissue structures and have provided specific information about the optimum frequency for microwave heating applications. Theories based on the consideration of a plane wave incident upon a planar multi-layer biologic sample indicate that a microwave diathermy frequency of 915 MHz is more desirable than 2.45 GHz because of increased penetration and less power deposition in superficial fat layers. Numeric solutions to a biologic model of Mie's theory for spherical scattering have resulted in some very interesting internal power deposition profiles. For example, a 14-cm diameter spherical body, the size of a human head, focuses substantial amounts of power at its center (much like a spherical lens) at 915 MHz. Other results have indicated that the maximum power absorption resonance region for man occurs near 70 MHz when man's height equals the free-space wavelength multiplied by a factor of 0.4. These theories and experiments have further indicated that the power absorption varies greatly with the orientation of a biologic body with respect to the electromagnetic field vectors.

5139 ECOLOGICAL INFLUENCE OF ELECTRIC FIELDS. *(Eng.)* Kornberg, H. A.; Bankoske, J. W.; McKee, G. W.; Graves, H. B. (Westinghouse Electric Corp., 700 Braddock Ave., East Pittsburgh, PA 15112). 47 pp., 1976. [available through National Technical Information Services, Springfield, VA 22161, Document No. PB 260 641]. (6 refs)

Studies on the effects of electric fields on plants, meadow voles, chicks, and chicken embryos are reported. Plant leaf tip damage was observed for certain pointed leaves at field intensities of 25 kV/m or greater, but no leaf tip damage was observed at field strengths of 20 kV/m or less. The damage observed was minor, however, and self-limiting. Electric fields no greater than 17.2 kV/m are anticipated 2 m above ground level underneath 1500-kV transmission lines. Meadow voles were exposed to 50 kV/m fields for periods up to 4 wk, and no statistically significant effects as a result of this exposure were observed. Chicks exposed to 40 and 80 kV/m fields exhibited a short term increase in early growth, which amounted to 5-10% in magnitude for body weight differences; however, there were no observed differences between exposed and unexposed chicks by 20 days after hatching. No effects from short-term exposure to fields up to 67 kV/m no egg hatchability or embryo behavior were observed.

5140 RADIO FREQUENCY ERADICATION OF TUMOURS. *(Eng.)* Whalley, W. B. (891 Loma Verde Ave., Palo Alto, CA 94303). *Electronics and Power* 23(5): 415-417; 1977. (2 refs)

An electric field approach to the radiofrequency (RF) eradication of tumors is described. Preliminary experiments involving the use of a 300-W amateur radio transmitter to heat a sodium chloride water solution, similar in salt concentration to human tissue and blood, indicated that passing an electric current through the solution resulted in uniform temperature increases throughout the solution. A thermometer, which was 15 cm away from the electrodes, rose uniformly with thermometers close to the electrodes. For experiments on dogs and humans, a frequency of 13.56 MHz and a current magnitude of 0.2 A

(root mean square)/cm of electrode diameter were chosen. It was necessary to tie together the outer sheaths of the coaxial cable lead wires at the ends close to the electrodes to provide optimum current flow between the electrodes. An inductor was inserted inside an insulating handle attached to the electrodes to neutralize the capacitive reactance between the electrode and the body tissue. A direct current inverse feedback loop between RF output and the master crystal oscillator was used to provide high stability at a given power setting and constant current at various electrode spacings. Experiments with dogs and humans indicate that the usual time for a successful treatment of a tumor is 30 min. In general, human malignant tumors change to a sack of liquid containing dead cells after RF treatment. If the tumor is less than about 50 mm in its largest dimension, the patient's body automatically removes the liquid and dead cells through the normal circulatory system. When the tumor is larger, the liquid from the treated tumor can often be removed with a hypodermic needle. The method allows for the selective destruction of tumors and damages only a very small volume of tissue directly in contact with the tumor.

5141 TEMPERATURE MEASUREMENT IN MICROWAVE DIATHERMY FIELDS: PRINCIPLES AND PROBES. *(Eng.)* Cetas, T. C. (Temperature Section, Heat Div., Natl. Bureau Standards, Washington, DC 20234). 12 pp; 1976. [available through National Technical Information Services, Springfield, VA 22161, Document No. PB 259 744]. (17 refs)

Probes for measuring temperature in microwave diathermy fields are discussed. Although thermistor-based devices assembled with microwave integrated circuit techniques are suitable for measurements in media that absorb power (heat) as readily as bone, they are unsuitable for nonabsorptive materials. Developments in passive thermometer probes include an optical thermometer probe that uses only dielectric nonabsorptive components. A probe that uses the reflectance of red light from a mixture of liquid crystals as the sensitive parameter has been developed with a temperature range of approximately 25-50 C and an instrumentation resolution of better than 0.1 C. Hysteresis effects and drifting in the liquid crystal result in temperature uncertainties of 0.3-0.5 C. Another type of liquid crystal thermometer has been developed that uses the optical rotary power of the liquid crystal mixture. A sandwich composed of a dichroic polarizer, the liquid crystal mixture, a polarization analyzer, and a mirror are attached to a bundle of optical fibers; the reflected light intensity is related to the sensor temperature. An optical thermometer that uses the birefringence of a pure single crystal as the thermometric parameter has also been constructed. The sensor consists of a dichroic polarizer, the crystal, and a dielectric mirror mounted at the end of a pair of fiber optic bundles. Output signals from the latter type of probe range from 0.1-1 V, with sensitivities of up to 30 mV/°C. The noise level is less than 1 mV. Thermometers based on this principle have been designed with a temperature range of 11-68 C.

5142 RADIOFREQUENCY HEATING OF TUMOURS IN RODENTS. *(Eng.)* Dickson, J. A. (Cancer Res. Unit, Univ. Dept. Clinical Biochemistry, Royal Victoria Infirmary, Newcastle upon Tyne, Great Britain); Calderwood, S. K.; Jasiewicz, M. L. *Eur Cancer* 13(7): 753-763; 1977. (42 refs)

The use of low power (less than 6 W) radiofrequency (13.56 MHz) heating for the treatment of rodent tumors is reported. The tumors were included in the output circuit of the radiofrequency generator by capacitive coupling between paddle electrodes, which were applied directly to opposite sides of the tumor mass. A 100% regression rate was obtained for MC7 sarcomas and Yoshida sarcomas (tumor volume, 1-1.5 ml) growing subcutaneously in the foot or flank of rats when these tumors were heated at 45 C for 15 min. When large (6-12 ml) Yoshida tumors in leg muscles were heated at 45 C for 30 min or 50 C for 15 min, all rats died soon after treatment. Subcutaneous D23 carcinomas (0.7-1.5 ml) in rats were not cured by hyperthermia at temperatures up to 45 C for 15 min. Mice bearing Ehrlich ascites tumors, which were heated at 42 C for 1 hr, 43 C for 30 min, or 44 C for 15 min died during or immediately after heating as did normal mice receiving the same hypothermic treatment. When both rear legs of rats bearing 6 ml intramuscular Yoshida tumors were heated to 45 C for 15 min, the normal muscle of the rat maintained a temperature that was consistently 2-3 C higher than the tumor. The electrical resistance of the heated tissue was not altered by the presence of tumor, and it appears that blood flow in this tumor was greater than in adjacent normal tissue. Therefore, there seems to be an upper limit on the temperature/time regimen that can be used to destroy the tumor.

5143 ENDORPHINS IN BRAINS OF DECAPITATED AND MICROWAVE-KILLED MICE. *(Eng.)* Cheung, A. L. (Addiction Res. Foundation and Stanford Univ., Palo Alto, CA 94305); Stavinoha, W. B.; Goldstein, A. *Life Sci* 20(7): 1285-1290; 1977. (27 refs)

The size distribution of opioid peptides (endorphins) in the brains of Swiss male mice undergoing either decapitation or quick killing by microwave irradiation (2,450 MHz for 200 msec) was determined by gel filtration. Inhibition of stereospecific ^{3}H-labeled etorphine binding to guinea pig brain membranes was used as a measure of endorphin activity. Three peaks of endorphin activity were observed. The first peak, just beyond the void volume, eluted in the position that would correspond to β-endorphin. This also corresponded to the elution behavior of the 3,000-dalton endorphin found in beef brain. The second peak, of intermediate size, probably corresponded to the endorphin of about 1,400 daltons in beef brain. The third peak, which emerged beyond the salt volume, eluted in the same position as ^{3}H-leucine-enkephalin. In all three experiments, every peak had somewhat lower activity after decapitation than after microwave killing, suggesting that some degradation may have occurred in situ after decapitation. However, there was no indication of preferential loss of any peak in the decapitated animals as compared with

those killed by microwave irradiation. The possibility of differential degradation of the three peaks during the binding assay was investigated by performing assays with and without bacitracin, an inhibitor of peptidase action on opioid peptides. The relative contribution of any particular size class to the total brain endorphin activity was not found to be selectively underestimated in the original experiment. Opioid peptides of all three size classes appear to be present in the brain in vivo.

5144 THE HUMAN MAGNETOENCEPHALOGRAM: SOME EEG AND RELATED CORRELATIONS. *(Eng.)* Reite, M. (EEG Lab., Dept. Psychiatry, Univ. Colorado Medical Center, 4200 East Ninth Ave., Denver, CO 80220); Zimmerman, J. E.; Edrich, J.; Zimmerman, J. *Electroencephalogr Clin Neurophysiol* 40: 59-66; 1976. (13 refs)

Simultaneous magnetoencephalographic (MEG) and electroencephalographic (EEG) data were recorded from six normal adult subjects in a shielded enclosure. MEG signal strength and EEG voltage level appeared to be linearly correlated. Spectral analysis suggested that the MEG and EEG data were produced by similar but nonidentical generator systems. A well-defined vertex region-evoked response to a visual flash was recorded in only one of four subjects exposed to the stimulus; the response was similar to the simultaneous EEG evoked response, with the two responses being nearly 180 degrees out of phase. In this case, cortical negativity was associated with a magnetic field directed into the scalp. Eye movement artifact, which can seriously compromise EEG recordings, did not appear to be a major problem in MEG recordings.

5145 THE PHYSICAL CHARACTERISTICS OF EM FIELD INTERACTION WITH MOLECULAR SYSTEMS. *(Eng.)* Anonymous. (No affiliation given). *Neurosci Res Program Bull* 15(1): 62-64; 1977. (0 refs)

The interaction of electromagnetic fields with molecular systems is discussed. Electromagnetic (EM) waves penetrate a conducting material to a depth that is a function of the frequency of the wave and the conductivity of the material. Therefore, EM waves exhibit skin effects, i.e., they remain near the surface of most conducting materials. For the microwave spectrum, maximum energy absorption in tissue occurs near the surface and decreases sharply at increasing depths. The magnetic component of an EM wave could interact with the magnetic component of spinning atomic nuclei, but even for a magnetic field of 10,000 G, the energy of interaction would be of the order of 1 Kelvin (K), and the coupling of such a field with brain tissue would be negligible. The coupling energy in the earth's magnetic field is of the order of 10^{-8} K for typical ring molecules oriented with the magnetic field. Ringlike structures, such as, benzene or naphthalene, which act like diamagnetic material, are unlikely to be the basis of a significant interaction with EM fields. However, if tissue molecules are organized as in a liquid crystal, the van der Waals forces would be strong enough to couple one molecule to another, producing a swarmlike structure. It is suggested that a biologic system with molecular properties of swarming could act as an information-processing device. A chain of neurons with this property could detect the forces of an electric field applied along the chain. The cerebellum is suggested as being a highly organized structure that is suitable for testing this model.

5146 EVIDENCE FOR ELECTRICALLY INDUCED PARTIAL STRAND SEPARATION OF DNA. *(Eng.)* Pollak, M. (Dept. Physics, Univ. California, Riverside, CA 92502); Glick, H. A. *Biopolymers* 16(5): 1007-1013; 1977. (8 refs)

Electrically induced changes in optical properties of calf thymus DNA-salt solutions were measured. Electric fields were applied in the form of 50-300 μsec pulses at field strengths up to 20 kV/cm. The following qualitative predictions expected from the theory of electrically induced partial denaturation of DNA were observed: a decrease in the reduced dichroism at high fields, a concurrent increase in the absorption coefficient, a critical field (about 14 kV/cm) above which the first two effects began to occur, a decrease in the magnitude of the above effects with increasing salt (sodium phosphate) concentration, and a return to the status quo ante after short pulses (about 50 μsec). The above experimental findings support the prediction that fields of the order of 10 kV/cm can induce a partial strand separation in DNA.

5147 THE PROPERTIES OF BIRD FEATHERS AS CONVERSE PIEZOELECTRIC TRANSDUCERS AND AS RECEPTORS OF MICROWAVE RADIATION. I. BIRD FEATHERS AS CONVERSE PIEZOELECTRIC TRANSDUCERS. *(Eng.)* Bigu-Del-Blanco, J. (Anatomy Dept., Queen's Univ., Kingston, Ontario, Canada); Romero-Sierra, C. *Biotelemetry* 2: 341-353; 1975. (22 refs)

The properties of bird feathers as piezoelectric transducers in the audiofrequency range and as dielectric receptors of electromagnetic radiation in the microwave range were studied. Parts of the inner and outer surfaces of calami removed from bird feathers were painted with silver paint, and two fine wire electrodes were electrically secured to each painted surface. Excitation of the feathers was performed with an audio amplifier and matching transformer that were driven by a sine wave oscillator. The excitation voltage (100-300 V, peak-to-peak) was swept through a frequency range of 1-20 kHz. Mechanical vibrations induced in the specimen by the applied signal were detected with a piezoelectric ceramic phonograph cartridge or with a low impedance broad-band electromagnetic transducer. The phonograph cartridge gave little response above 15 kHz; whereas, the electromagnetic transducer had a frequency range extending to the MHz range. The results revealed piezoelectric resonances in the 1-20 kHz region for the calami of feathers. A

linear relationship between specimen electrical output and electric field strength between the electrodes indicated that the observed effect was strictly first order (piezoelectric) rather than electrostrictive (dependent on the square of the electric field). Signal amplitude at resonance decreased as a function of increasing feather area subjected to electrical stress. Increasing relative humidity decreased the amplitudes of the resonance peaks, and increasing temperature resulted in a decrease in resonance frequency. The electric field strength across the specimens excited was about 22 V/cm per V of applied voltage. Thus, for the voltages normally used, electric field strengths of several thousand V/cm were obtained.

5148 THE EFFECT OF WEAK MAGNETIC FIELDS ON SOME BACTERIAL SPECIES. *(Rus.)* Vyorkin, B. I. (Physio-Technical Low-Temperature Inst., Acad. Science, USSR); Bondaryenko, S. I.; Shermet, V. I.; Tsutsaeva, A. A.; Safonova, T. S.; Yurchenko, G. G. *Mikrobiologia* 45(6): 1067-1070; 1976.

The effects of weak magnetic fields on bacterial species are described. The bacteria involved in this study were *Escherichia coli, Staphylococcus aureus 209, Serratia marcescens, Bacteriodes anthracoides*. The bacteria were cultivated in a weak magnetic field for 4 mo and transferred to fresh medium every 18 hr at 37 C. The control bacteria were grown in the same way under conditions of a constant geomagnetic field. Every 15 days, the microorganisms were checked for change. Changes in staining, morphology, culture and biochemistry occurred after 2 mo. Metachromatic deviations were seen in gram stains of *E. coli* and *S. marcescens*. In *Staph. aureus 209*, disconnected single cocci predominated; in *Bac. anthracoides*, rod dimensions were larger, and they stained more intensely. Under the protracted influence of weak magnetic fields, gas and acid formation of the bacteria either increased or decreased depending on the type of sugar in the culture medium.

5149 MECHANICAL MASSAGE WITH ELECTRICAL FIELD: A NEW COMBINATION THERAPY. *(Ger.)* Klemm, J. (Rontgenabteilung, II. Med. Univ.-Klinik, Ziemssenstrasse 1, 8 Munich 2, W. Germany). *Fortschr Med* 95(13): 851, 854; 1977.

The pain-relieving effect of vibratory massage combined with electrical field (0-30 V) was studied in 44 patients with gelosis of the splenius and trapezius muscles and traumas. The pain threshold was measured by the Seeligmuller-Trummer algimetric method 5 min after treatment. The treatments were given four times a day. Vibratory massage combined with electrical field increased the pain threshold by 30-40%, while massage alone caused an increase of only 15-20%. The pain threshold increased by 98% after 12 treatments in cases of recent trauma. The combined therapy also alleviated mild inflammatory processes and improved motion. It is recommended for the treatment of rheumatoid diseases, neuralgia, and dull trauma.

5150 ELECTRIC BIREFRINGENCE STUDIES OF CARTILAGE PROTEOGLYCAN AGGREGATION. *(Eng.)* Foweraker, A. R. (Physics Dept., Brunel Univ., Uxbridge, Middlesex, U.K.); Isles, M.; Jennings, B. R.; Hardingham, T. E.; Muir, H. *Biopolymers* 16(6): 1367-1369; 1977. (10 refs)

Electric birefringence measurements were made on a sample of pig laryngeal proteoglycan exposed to electric fields. Electric fields of up to 600 V/cm with pulse durations of up to 160 msec were applied to solutions of proteoglycans in distilled water containing 209 µg/ml of uronic acid. The sample exhibited a large birefringence and a rotary relaxation time of 3.6 ± 0.3 msec. A hyaluronic acid solution of 20 µg/ml uronic acid (approximately 60 µg/ml of hyaluronic acid) was added in steps of 0.1 ml to 10 ml of the proteoglycans solution and successive optical transients were recorded. Birefringence amplitude changed significantly, and its sign was also possibly changed. A change in birefringence sign is consistent with the reversal of the optical anisotropy from the proteoglycan to the aggregated molecules. The relaxation time of the complex was about 650 ± 30 msec of 180 times that of the constituent proteoglycan molecules. Treating the individual proteoglycan molecules as prolate ellipsoids of 40 nm semiminor axes, a rotary relaxation time of 3.6 ± 0.3 msec corresponds to a molecular length of 380 ± 20 nm, which is in reasonable agreement with a previous estimate of 300-400 nm and which suggests that the molecule was maximally extended under the conditions of low ionic strength used in this study.

5151 DIATHERMY VERSUS THE MICROWAVES AND OTHER RADIO-FREQUENCY RADIATIONS: A ROSE BY ANOTHER NAME IS A CABBAGE. *(Eng.)* Justesen, D. R. (Lab. Experimental Neuropsychology, US Veterans Admin. Hosp., Kansas City, MO 64128). *Radio Science* 12(3): 335-364; 1977. (31 refs)

Weak-field and strong-field hazards associated with microwave and radiofrequency radiation are discussed. Focal or general thermal insult from simple heating of tissues can, in principal, result from exposure to fields as low as or even lower than 1 mW/cm^2, although the practical likelihood of damage at this density is remote. There is a scientific consensus that exposure to radiofrequency fields of high flux density, 100 mW/cm^2 or more, are thermally dangerous, and there is an increasing prevalence of belief that lengthy exposures to fields between 1 and 100 mW/cm^2 may be thermally dangerous. Animal experiments with microwaves have produced paradoxic results in some cases. When male mice were irradiated with 3-cm microwaves for 4.5 min/day, 5 days/wk for a maximum of 59 wk at an incident power density of 100 mW/cm^2, radiation-induced testicular damage was observed; however, an analysis of the survival data indicates that irradiated mice lived longer than controls. In another experiment where fetal mice were irradiated with 2,450-MHz microwaves and were then injected on the 16th day postpartum with a homogenate of a lymphoreticular cell sarcoma, the irradiated mice had a low incidence of tumor takes (3/24) as compared

with controls (11/24), suggesting that intrauterine exposure to microwave radiation may enhance the development of immunologic competency. It is suggested that only when dosimetry is adopted as a rule of procedure in the laboratory will consensual resolution to the existence and nature of weak-field hazards, thermal and nonthermal, be achieved.

5152 ON MICROWAVE-INDUCED HEARING SENSATION. *(Eng.)* Lin, J. C. (Dept. Electrical and Computer Engineering, Wayne State Univ., Detroit, MI 48202). *IEEE Trans Microwave Theory Techniques* 25(7): 605-613; 1977. (28 refs)

A theoretic analysis of the acoustic wave generated in the heads of animals and man exposed to pulsed microwave radiation as a result of rapid thermal expansion is presented. Using a spherical model of the head, the problem was formulated in terms of thermoelasticity theory in which the absorbed microenergy represented the volume heat source, which depended on both space and time. The inhomogeneous thermoelastic motion equation was solved for the acoustic wave parameters under stress-free surface conditions using boundary value technique and Duhamel's theorem. The numeric results indicated that pulsed microwave-induced sound pressure amplitude depended on both pulse width and peak power density. In addition, there is apparently an optimal pulse width for maximum sound pressure generation, which varies according to the sphere size and the frequency of the impinging radiation. For a peak absorbed power density of 1,000 mW/cm^3, which corresponds to 600 mW/cm^2 incident power at 2,450 MHz impinging on a 3-cm spherical head, and to 2,200 mW/cm^2 incident power at 918 MHz impinging on a 7-cm spherical head, the pressure amplitudes generated at the center of the sphere are 15-30 dB above the reported threshold of hearing by bone conduction (60 dB) 0.0002 dyne/cm^2, 5-10 kHz) for pulses between 1 and 50 μsec wide. Estimations of the fundamental sound frequency generated inside the head show that the frequency varies from about 8 kHz for a man-sized sphere to approximately 80 kHz for a small animal's head, such as mouse's head. Assuming an equivalent radius of 1.5 cm for the brain of a guinea pig, a fundamental sound frequency of 48 kHz is calculated; this is in reasonably good agreement with the 50-kHz cochlea microphonic oscillations recorded from the round window of guinea pigs.

5153 PHYSICAL ENVIRONMENTAL FACTORS. *(Eng.)* Ferris, B. G.; Cook, R.; Elder, J. A.; Horvath, S. M.; Lamola, A.; Mills, W. A.; Storer, J. B.; Von Gierke, H. E.; Walsh, P. *In: Human Health and the Environment--Some Research Needs.* (Washington, DC: Dept. Health, Education, and Welfare): Report of the Second Task Force for Research Planning in Environmental Health Science. vol. 2, pp. 127-181; 1977. (96 refs)

The biologic effects associated with various forms of nonionizing radiation are reviewed. Thermal hazards have been established for exposure to microwave radiation (300 MHz to 300 GHz), particularly for temperature-sensitive systems such as the avascular lens of the eye and the male gonads. Short-term acute exposures of animals to power levels in excess of 100 mW/cm^2 have been observed to cause cataracts and temporary sterility. Recent reports suggest biologic effects on the central nervous system (CNS), heart, and chromosomes, in addition to the effects of radiofrequency heating, as a result of exposure to low levels (less than 10 mW/cm^2) of nonionizing radiation. The effects are apparently separate from generalized heating injury. Regarding exposure to extra-high voltage transmission lines (345 kV or above), most studies fail to reveal any prompt or acute adverse effects in humans or animals. However, effects of extremely low frequency (ELF) fields on the CNS have been reported, which suggest that ELF field thresholds are frequency-dependent and affect the CNS in a manner that takes days to fully attenuate. Research is continuing on the effects of ELF, particularly in the 60 Hz range, which is the standard frequency of electrical power in the United States. Other sources of nonionizing radiation include near-visible ultraviolet light and visible light. Reactions elicited in humans by such radiation occur in the presence of photosensitizers or under abnormal conditions such as those involved in immune system hypersensitivity.

5154 BIOLOGICAL EFFECTS OF MICROWAVE RADIATION. *(Pol.)* Bogucka, A. (Affiliation not given). *Ochrona Pracy* 31(2): 4-5; 1977.

A total of 72 workers exposed to electromagnetic fields in television and radio work in the USSR had a variety of complaints from epigastric pain to hyperacidity; hypoacidity was seen in persons working longer than 10 yr. In 69%, functional disorders of the central nervous and cardiovascular systems were observed. Microwave irradiation also led to leukopenia and simultaneous eosinophobia of the blood. These disorders were initially reversible in the majority of cases, but long-term radiation could turn them irreversible requiring thorough treatment. Occupational change was seen as indispensible for afflicted workers. Contraindications for this line of work include active tuberculosis, diseases of the blood, central nervous system, endocrine glands, and eyes, and vegetative neurosis. Periodic medical checkups with particular attention to eyes, central nervous system, alimentary tract, and the hematopoietic system were considered a necessity.

5155 POLLUTION CAUSED BY HIGH FREQUENCY ELECTROMAGNETIC FIELDS. *(Ita.)* Bernardi, P. (No affiliation given). *Securitas* 61(1-2): 9-16; 1976. (0 refs)

Protection from electromagnetic pollution due to microwaves (300-100,000 MHz) or radiofrequencies (1-300 MHz) generated by communication systems, radar and science installations, medical apparatus, domestic appliances, and industrial machinery is

discussed. Thermal (general or localized) and nonthermal (weak or strong) effects are reviewed with reference to machinery using electromagnetic heating. Studies using electromagnetic models have established that the type of irradiation source (shape, dimensions, and interaction area), the location (housing of iron or reinforced concrete; other objects present in the area), and the type of irradiated structure (humans, animals, and in vitro tissues) are the factors which influence the interaction of electromagnetic waves and biologic tissue. Several methods for measuring increased body temperature resulting from exposure to radiofrequency machinery are listed. Screening irradiation sources, heating part of the machinery, modifying machinery housing, wearing protective clothing, and working shorter hours are suggested as protective measures against electromagnetic pollution.

5156 MICROWAVE RADIATION-MEDICAL SURVEILLANCE. *(Eng.)* Tyler, P. E. *Presented at the 1976 International Microwave Symposium in Cherry Hills, NJ).* 5 pp.; 1976. (0 refs)

A plan for medical surveillance of workers occupationally exposed to microwave radiation is discussed. The Medical Surveillance Subcommittee of the American National Standards Institute is developing a physical examination, which is designed to protect both the employer and employee; at the same time, this examination may provide a basis for observing trends in the physical condition of employees exposed to electromagnetic radiation. The Committee recommends that a normal industry pre-employment physical examination be developed encompassing the following tests: lipid profile (fasting sample) including total lipids, cholesterol, triglycerides, and phospholipids; serum cortisol (morning sample); immunoglobulin electrophoresis; complete blood count test including hematocrit (capillary tube methods), white blood cell count, red blood cell count, and differential; dilated ophthalmologic examination including a biomicroscopic examination for opacities, vacuoles, and posterior subcapsular irradiance; opthalmoscopic examination of fundus oculi; and a routine neurologic examination. It is also recommended that a note be made in the medical history of previous exposure to occupational ionizing or nonionizing radiation. If adequate facilities are available, T-3 and T-4 tests for thyroid evaluation should be included as well as an electroencephalogram.

5157 THE LEVELS OF GABA IN MOUSE BRAIN FOLLOWING TISSUE INACTIVATION BY MICROWAVE IRRADIATION. *(Eng.)* Knieriem, K. M. (State Lab. Hygiene, Univ. Wisconsin, Center for Health Sciences, Madison, WI 53706); Medina, M. A.; Stavinoha, W. B. *J Neurochem* 28(4): 885-886; 1977. (20 refs)

Levels of gamma-aminobutyric acid (GABA) in mouse brain following tissue inactivation by microwave irradiation were determined. Sprague-Dawley mice were positioned in a waveguide chamber perpendicular to the microwave E field for exposure to 2,450-MHz microwave radiation. The instrument delivered 5.5 kW directly to the mouse head. After 200, 300, or 400 msec of microwave exposure, the mean GABA level was 1.9 μmol/g of tissue. After exposure to 200 msec of microwave radiation, the activity of glutamate decarboxylase and GABA-transaminase was 5 and 25%, respectively, that of control values. From these results, 200 msec was chosen as an adequate time to stabilize postmortem brain GABA levels. The GABA concentration in the brain of microwave-irradiated mice was comparable to that found in mice and rats after rapid freezing. A comparison of decapitated versus irradiated mice indicated that the levels of brain GABA in the decapitated group were 14% higher than those found in irradiated animals. If the brain was removed and allowed to remain at room temperature for 30 min prior to homogenization, the brain GABA levels increased by 19% in decapitated mice, while no difference was observed in irradiated animals. Therefore, exposure to 200 msec of microwave irradiation effectively prevented postmortem elevation of brain GABA. When GABA levels were determined in eight discrete brain areas from six animals killed by exposure to 200 msec of microwave radiation, the lowest GABA values were found in the cerebellum (0.88 ± 0.08 μmol/g) and the highest in the hypothalamus (3.55 ± 0.08 μmol/g).

5158 LEVELS OF CYCLIC NUCLEOTIDES IN MOUSE REGIONAL BRAIN FOLLOWING 300 MS MICROWAVE INACTIVATION. *(Eng.)* Jones, D. J. (Dept. Anesthesiology and Pharmacology, Univ. Texas Health Science Center, San Antonio, TX); Stavinoha, W. B. *J Neurochem* 28(4): 759-763; 1977. (27 refs)

The uniformity and speed of inactivation of mouse brain adenylate cyclase, guanylate cyclase, and cyclic nucleotide phosphodiesterase were measured after white Swiss mice were exposed to 6-kW of microwave radiation. Inactivation of the enzymes was uniform throughout the brain during microwave heating. Activities of adenylate cyclase, phosphodiesterase, and guanylate cyclase were reduced by 100% after heating times of 200, 300, and 150 msec, respectively. When exposure to 6-kW microwave radiation for 300 msec was compared with exposure to 1.5-kW radiation for 4 sec, the level of cyclic adenosine 3', 5'-monophosphoric acid (AMP) in all brain areas except the corpus striatum was at least 50% lower in the 6-kW, 300-msec exposed animals than in the 1.4-kW, 4-sec exposed animals. In the corpus striatum, a 33% difference according to the above trend was observed. Cyclic guanosine 3', 5'-monophosphoric acid (GMP) levels did not significantly differ between the two exposure groups. When cyclic AMP and cyclic GMP levels were measured from the same regional brain tissue samples, the ratio of cyclic AMP:cyclic GMP varied from 1.5-11.5 after 300 msec deactivation treatment as compared with 3.4-19.1 after 4-sec deactivation treatment. The ratios after 300 msec heating were much lower than those previously reported after liquid nitrogen freezing was used for enzyme deactivation, suggesting that slow inactivation times provide for the measure-

ment of regional brain cyclic nucleotide values, which are not consistent with the in vivo state. A maximal field strength of 6 kW microwave radiation provides for the accurate measurement of cyclic nucleotides in various regional areas of the brain by minimizing the effects of processes that alter the levels during inactivation of this tissue.

5159 NON IONISING ELECTROMAGNETIC FIELDS: ENVIRONMENTAL FACTORS IN RELATION TO MILITARY PERSONNEL. *(Eng.)* Servantie, B.; Tyler, P. E. (Defense Medical Service, France). 31 pp.; 1976. [available through National Technical Information Services, Springfield, VA 22161, Document No. AD A035844]. (140 refs)

Thermal and nonthermal effects of microwave radiation are reviewed with emphasis on the exposure of radar personnel to microwave radiation. Information about human pathology due to the thermal effects of microwaves is very poor. Peritonitis and subsequent death was reported to have occurred in a technician working approximately 3 m from an antenna. Two cases of infarction of the spleen with hemorrhage following severe irradiation have also been reported. Oligospermia with infertility reportedly occurred in a man exposed several times to intense irradiation. Severe headache followed by a meningeal syndrome was observed in an engineer working on a parabolic aerial-emitting X-band radiation. Experimentally, it has been shown that general irradiation at high power densities leads to the death of an animal through hyperthermia. Hyperthermia caused in this way is accompanied by salivation, behavior indicating a desire to escape, and convulsions. Localized irradiation of the head may produce similar manifestations. Other organs that are particularly sensitive to the thermal effects of microwave radiation are the testicles and the lens of the eye. Soviet reviews have published a large number of cases of occupational diseases found in technicians working for some time in an electromagnetic environment. The clinical signs are numerous and cover the endocrine glands, cardiovascular, and nervous systems. Experimentally, a large number of biologic effects have been observed in animals exposed to low power densities, generally less than 10 or even 1 mW/cm^2. Such effects include: microwave-induced auditory sensations; disorders in behavior, neuromuscular functioning, and balance; increased egg production by hens; changes in electroencephalographic recordings; changes in certain biologic rhythms; mitotic changes; and hormonal, biochemical, and blood changes. A discussion of safety standards and health protection of personnel working in the vicinity of microwave radiation is also presented.

5160 APPARENT REGIONAL TURNOVER OF ACETYLCHOLINE IN MOUSE BRAIN: METHODOLOGICAL AND FUNCTIONAL ASPECTS. *(Eng.)* Nordberg, A. (Dept. Pharmacology, Faculty Pharmacy, Univ. Uppsala, Biomedical Center, Box 573, S-751 23 Uppsala, Sweden). *Acta Physiol Scand* 445(Suppl.): 7-50; 1977. (108 refs)

Studies on the levels of acetylcholine (ACh) in different brain regions of mice following alternative methods of sacrifice by microwave irradiation are reviewed. To achieve a shortened enzyme inactivation time two methods of microwave killing were used: whole body 2,450-MHz microwave irradiation for 7 sec (1.3 kW; brain temperature of 85-90 C at 11 sec postirradiation) and 2,450-MHz irradiation of the head for 0.25 sec (5 kW; brain temperature of 85-90 C at 10 sec postirradiation). A markedly higher content of tritium-labeled ACh was preserved, especially in the striatum, when the time of enzyme inactivation was reduced from 7 min (decapitation) to 7 sec (microwave). A comparable increase in the steady state concentration of ACh was obtained by reducing the time of enzyme inactivation further to 0.25 sec (microwave irradiation). These findings indicate the existence of several pools of ACh in the brain. Although ACh in the brain region does not appear to be homogeneous, plots of the specific radioactivities of ACh and choline (Ch) at different time points after the injection of tritium-labeled Ch indicate a precursor-product relationship in all brain regions (except the cerebellum) at the shorter enzyme inactivation time (0.25 sec, microwave).

5161 ELECTRIC FIELD EFFECTS IN BACTERIORHODOPSIN. *(Eng.)* Shinar, R. (Dept. Physical Chemistry, Hebrew Univ. Jerusalem, Jerusalem, Israel); Druckmann, S.; Ottolenghi, M.; Korenstein, R. *Biophys J* 19(1): 1-5; 1977. (16 refs)

The exposure of aqueous suspensions (1.5×10^{-5} molar) of fragments of the purple membrane of *Halobacterium halobium* to a strong transient electric field applied in a (Joule heating) temperature-jump instrument led to transient linear dichroism phenomena. Experiments in which the analyzing light beam was plane-polarized parallel or perpendicular to the applied electric field (about 10 kV/cm) were conducted to discriminate between T-jump and orientational electric field effects. Transient changes in absorbance were found to be almost exclusively due to a time-dependent linear dichroism. Two observed relaxation times were observed. One (about 100 msec) was attributed to rotation of the whole membrane fragments, while the other (about 260 μsec) was attributed to a much faster reorientation of the chromophore within the membrane.

5162 ELECTROKINETIC PROPERTIES OF BLOOD ELEMENTS UNDER THE EFFECT OF PHYSICAL FACTORS. *(Rus.)* Rusiaev, V. F. (Chita State Medical Inst., Chita, USSR); Kuksinskii, V. E.; Sheftel', I. E. *Biofizika* (47): 679-683; 1976. (16 refs)

The effect of the electromagnetic field on the electrophoretic properties of the blood was studied in in vitro experiments. Human and dog erythrocytes and thrombocytes were irradiated (10 min) with a constant magnetic field (300 Oe), with variable electric fields (3 V/cm, 50-20,000 Hz) and with acoustic fields (50-20,000 Hz). In all experiments, irradiated erythrocytes and thrombocytes showed a

decrease in the electrophoretic mobility. The highest effect was observed at 500-1,000 Hz for both acoustic and electromagnetic fields.

5163 MOTOR ACTIVITY OF MUSCLES IN A MAGNETIC FIELD OF VARYING INTENSITY. *(Rus.)* Andrianova, L. A. (No affiliation given); Smirnova, N. P. *Kosm Biol Aviakosm Med* 11(1): 54-58; 1977. (8 refs)

The effect of a constant magnetic field (250-4,000 Oe, exposure 10-30 min) and an alternating magnetic field (100 Oe, 100 Hz) on the motor activity of muscles was studied in CBA mice by counting generated impulses during 10-min periods. Exposure to constant magnetic field with 4,000 Oe caused a significant reduction in the number of impulses (7.2 ± 1.9 during the first 10 min, 2.7 ± 0.9 during the second 10-min period, and 0.6 ± 0.2 during the third 10-min period; 7.7 ± 2.6 during the first 10 min after exposure, 13.5 ± 2.8 during the second 10-min period, and 13.3 ± 5.5 during the third 10-min period, vs 50.6 ± 7.6 before the exposure. The number of impulses was 16.63 ± 5.21 during the first 10 min, 9.47 ± 2.7 during the second 10 min, and 8.1 ± 2.94 during the third 10 min of exposure to the alternating magnetic field, vs 38 ± 4.1 before exposure. There were 9.63 ± 2.73 impulses during the first 10 min after exposure, 4.63 ± 0.68 during the second 10 min, and 3.31 ± 1.1 during the third 10-min period. Exposure to constant magnetic field with 1,000 Oe also inhibited the motor activity significantly, while exposure to 500 Oe slightly activated activity during and immediately after exposure.

5164 ACTION OF A LOW-FREQUENCY ELECTROMAGNETIC FIELD ON THE BODY IN CASE OF SHORT-TERM DAILY IRRADIATION. *(Rus.)* Koziarin, I. P. (A. A. Bogomolets Kiev Medical Inst., Kiev, USSR); Gabovich, R. D.; Popovich, V. M. *Gig Sanit* (4): 18-21; 1977. (0 refs)

To evaluate the health hazards of low frequency electromagnetic fields, 200 male albino rats were irradiated 2 hr daily for 4 mo. Animals were divided into six groups: Group I served as control; Group 2 was exposed to the field of 1 kW/m; Group 3 to 2 kW/m, Group 4 to 4 kW/m, Group 5 to 7 kW/m, and Group 7 to 15 kW/m. By the end of the experiment, animals in Groups 5 and 6 had significantly lower weight (261.6 ± 10.1 g and 253.9 ± 10.7 g, respectively) than controls (296.2 ± 10.7 g). By the end of the 2nd mo of the experiment, animals in Group 6, and by the end of the 3rd mo, animals in Group 5 showed significant decrease in the ratio of muscle reaction time (0.4 ± 0.04 and 0.5 ± 0.08, as compared with 1.9 ± 0.2 in the controls). Exposure to the electromagnetic field resulted also in the inhibition of the function of the thyroid gland (accumulation of ^{131}I dropped from 59.4 ± 3.6% in Group I to 40.8 ± 1.9% in Group 5 and to 47.2 ± 3.7% in Group 6); by the end of the 1st mo, rats in Groups 5 and 6 exhibited an increased level of residual nitrogen (28.2 ± 0.9 mg% and 30.3 ± 1.2 mg%, as compared with 24.8 ± 0.9 mg% in the controls), an increased level of urea (39.8 ± 1.6 mg% and 40.5 ± 2.1 mg%, while 29.7 ± 1.8 mg% in the controls) and an increased level of glucose (85.5 ± 1.3 mg% and 86.7 ± 2.9 mg%, while 77.5 ± 1.8 mg% in the controls). After the termination of the experiment all indices returned to the normal values. Data indicates that 7 kW/m was the threshold intensity and 3-7 kW/m was the subthreshold intensity of the electromagnetic field.

5165 A MICROWAVE RADIOMETRIC METHOD FOR THE STUDY OF THE SEMICONDUCTOR PROPERTIES OF LIVING TISSUE (MEETING ABSTRACT). *(Eng.)* Bigu-del-Blanco, J. (Dept. Anatomy, Queen's Univ., Kingston, Ontario, Canada); Schneiter, A.; Beal, J. C. *In: Book of Abstracts of Seventh European Microwave Conference: The International Conference and Exhibition Designed for the Microwave Community. 5th-8th September, 1977, Copenhagen, Denmark.* p. 70; 1977. (0 refs)

A microwave (MW) radiometric method for the study of the semiconductor properties of tissue was tested. This method employed the nonlinear properties of tissue in conjunction with its radiative properties as described by blackbody theory. The region of the body under examination was illuminated by a monochromatic MW field that mixed with the MW field generated by this region. This mixing resulted in an intermodulation spectrum (IS) that was detectable with a radiometer tuned to a predetermined frequency, or alternatively, to a sum frequency of the IS.

5166 MICROWAVE RADIATION (MR) HEATING OF SURFACE TUMORS (MEETING ABSTRACT). *(Eng.)* Block, J. B. (UCLA-Harbor General Hosp., Torrance, CA 90509); Hirose, F.; Battista, S. *Proc Am Assoc Cancer Res* 18: 306; 1977. (0 refs)

Microwave radiation (MR) was applied to cancers metastatic to the skin to define clinical tolerance and to establish doses of heating associated with objective changes in such tumors. Using a magnetron microwave source at 80 W/cm^2 (2.45 GHz frequency) and tissue coupler, 12 patients with multiple surface metastatic tumors were treated. Two patients with adenocarcinoma (primary uterus and colon) and 10 with melanoma were treated for up to 30 min. Needle thermistors were placed immediately beneath the skin (or tumor) surface at the site of MR and at the central irradiated tumor core (1-2.5 cm below the tumor surface). A technique for surface cooling and adjustment of MR permitted skin surfaces to be maintained between 41 C and 45 C with tumor core temperatures induced and maintained to 50 C with 1-4 W/cm^2. Two patients did not tolerate MR due to local pain. There was no clinical discomfort, evident toxicity, or residual surface burns in the remaining 10 patients. Tumor biopsy of MR-heated tumors demonstrated induction of massive necrosis with an abrupt demarcation from nonaffected deeper-lying tumor; lymphocytic infiltration of normal tumor tissue was occasionally seen at this interface.

Tumor regression was also observed. These studies demonstrated patient tolerance to MR heating and the potential for objective evaluation of MR dose-response curves for tumor regression in man.

5167 SOME EFFECTS OF LOW-LEVEL DOSAGES OF MICROWAVES ON ISOLATED NERVE ACTIVITY (MEETING ABSTRACT). *(Eng.)* Lott, J. R. (North Texas State Univ., Denton, TX 76203); Smith, G. H. *Radiat Res* 70(3): 690; 1977. (0 refs)

The effects of microwaves at dose levels below 10 mW/cm^2 on the activity of isolated sciatic nerve fibers from frogs (*Rana pipiens*) were determined. Changes in chamber temperature, action potential amplitude, and conduction velocity were recorded before and during exposure to microwaves. The nerves were stimulated every 30 sec during each experiment (360 min/wk). Photographs of the resultant action potentials were taken via an electronic thermistor. The microwave power generator was set to deliver about 42 W at 2,450 ± 25 MHz to the antenna horn. The chamber was located in an electrically sealed cage, and the antenna horn was placed 42 cm about the test nerve. Each test nerve was irradiated continuously during each experiment. The effects observed were: (1) a gradual and prolonged increase in the amplitude of the action potential followed by a sharp decline after about 4 hr of exposure, (2) a gradual and sustained increase in nerve impulse conduction velocity followed by a decline at 4 hr postirradiation, and (3) a slight but sustained increase in chamber temperature after 1 hr of exposure (1.4 C).

5168 INCREASE IN X-RAY SENSITIVITY OF CANCER AFTER EXPOSURE TO 434 MHZ ELECTROMAGNETIC RADIATION. *(Eng.)* Holt, J. A. G. *In: Digest of 1977 IEEE MTT-S International Microwave Symposium held in San Diego, CA on June 21-23, 1977.* Inst. Electrical and Electronic Engineers, Inc. (New York, NY): pp. 259-262; 1977. (8 refs)

The use of 434-MHz electromagnetic radiation 15 min before the application of low doses (50-80 rads) of X-radiation was found to enhance the proportion of cancer cells killed by a factor ranging from 3 to over 100 in comparison to X-irradiation alone. When three groups of 52 patients each all with proven eye, nose, or throat cancer were treated with megavoltage X-rays that were combined with 434 MHz irradiation in air, 3 atmospheres pressure of hyperbaric oxygenation, or simply air at 37 C, the corresponding rates of resolution of the primary tumor and involved lymph nodes were 81, 61, and 32%, respectively. The corresponding death rates during the first 2 yr after treatment were 42, 63, and 71%, respectively. Both response and survival duration were improved with the use of 434-MHz irradiation. The increased radiation sensitivity produced by 434-MHz irradiation appeared to be chiefly nonthermal in origin. Temperature measurements revealed a maximum differential rise of over 3.0 C in large avascular cancers. X-ray sensitivity of some cancers after 434-MHz irradiation remained enhanced for approximately 30 min, even when the tumor was cooled to its temperature before 434-MHz irradiation. A second period of increased X-ray sensitivity appeared to exist between about 20 and 30 hr after 434-MHz irradiation.

5169 A BOLUSING TECHNIQUE FOR BATCH MICROWAVE IRRADIATION OF TUMORS IN THE FAR FIELD. *(Eng.)* Cheung, A. Y.; McCulloch, D.; Robinson, J. E.; Samaras, G. M. *In: Digest of 1977 IEEE MTT-S International Microwave Symposium held in San Diego, CA on June 21-23, 1977.* Inst. Electrical and Electronic Engineers, Inc. (New York, NY): pp. 357-359; 1977. (6 refs)

A bolusing technique for the simultaneous irradiation of multiple mouse tumors (C3H/HeJ) in the far field is described. Each animal is enclosed within a cylindrical metal shield, with its superficial flank tumor drawn through a slot aperature for exposure to 2,450 MHz microwave hyperthermia. By encapsulating the tumor in a larger bolus of tissue-equivalent material, tumor heating uniformity was markedly improved (±0.15 C at 45 C heating). A replicable bolus shape was formed using expanded polystyrene molds. Placement of the tumor mold assemblies on an equipower surface of an anechoic microwave range permitted the simultaneous irradiation of multiple mouse tumors.

5170 PRELIMINARY IN-VIVO PROBE MEASUREMENTS OF ELECTRICAL PROPERTIES OF TUMORS IN MICE. *(Eng.)* Burdette, E. C.; Seals, J.; Toler, J. C.; Cain, F. L.; Magin, R. L. *In Digest of 1977 IEEE MTT-S International Microwave Symposium held in San Diego, CA on June 21-23, 1977.* Inst. Electrical and Electronic Engineers, Inc. (New York, NY): pp. 344-347; 1977. (7 refs)

In vivo probe measurements of dielectric properties of tissue exposed to microwave-induced hyperthermia are reported. The in vivo measurement probe is based on an antenna modeling theorem, which relates the impendance of a short monopole antenna in air to its impedance in a lossy dielectric medium. The system used to measure the impedance of the probe consists of a reflectometer in conjunction with a network analyzer. Measurements on standard materials (water and ethylene glycol) indicate that the probe is potentially useful at frequencies up to at least 8 GHz. Measurements on muscle-equivalent phantom modeling materials and tissue were performed only up to 2.0 GHz because of procedural limitations. Preliminary dielectric constant and conductivity measurements were made in vivo on canine thigh muscle tissue and six different malignant tumors in mice (Lewis lung carcinoma, melanotic melanoma B16, Barrett mammary adenocarcinoma, Mendecki mammary adenocarcinoma, glioblastoma, and ependymoblastoma) over a frequency range of 0.01-2.0 GHz. The resulting dielectric constant and conductivity values appear reasonable in relation to in vivo values previously measured using normal tissue. The above

measurement system, once automated with a swept frequency capability and an increased sensitivity, could represent a potentially useful diagnostic tool for differentiating between normal and malignant tissues.

5171 NEAR ZONE MICROWAVE OF A BIOLOGICAL SPHERE. *(Eng.)* Al-Badwaihy, K.; Hafiz, S. A. *In: Digest of 1977 IEEE MTT-S International Microwave Symposium held in San Diego, CA on June 21-23, 1977.* Inst. Electrical and Electronic Engineers, Inc. (New York, NY): pp. 352-353; 1977. (1 ref)

Power deposited into a spherical model of biologic tissues is computed for an exciting axial electric or magnetic dipole at different locations and for different frequencies. It is found that near zone fields may deposit higher power into biologic structures than plane waves having the same incident strength. The relative power deposited into the sphere increases as the dipole gets closer to the sphere and is larger for the magnetic dipole than for the electric dipole. The relative power is almost frequency independent in the frequency range 1-10 GHz because of the increase in conductivity of biologic tissues with frequency. The power distribution inside the sphere is frequency dependent, with lower frequencies showing more even power distribution than higher frequencies.

5172 TERATOGENIC POWER OF SHF FIELDS. FURTHER EXPERIMENTS ON *TENEBRIO MOLITOR* COLEOPTERON (MEETING ABSTRACT). *(Eng.)* d'Ambrosio, G. (Universita di Napoli, Istituto Electrotecnico, Naples, Italy); La Manna, V. *In: Book of Abstracts of Seventh European Microwave Conference: The International Conference and Exhibition Designed for the Microwave Community. 5th-8th September, 1977, Copenhagen, Denmark.* p. 71; 1977. (0 refs)

The frequency dependence of microwave-induced teratogenic effects in *Tenebrio molitor* was investigated. Power absorption of the specimen and the influence of the age of the exposed pupa was investigated. The previously known energy dosage law was also tested at various levels.

5173 NON-PERTURBING MICROPROBES FOR MEASUREMENT IN ELECTROMAGNETIC FIELDS. *(Eng.)* Deficis, A.; Priou, A. *In: Digest of 1977 IEEE MTT-S International Microwave Symposium held in San Diego, CA on June 21-23, 1977.* Inst. Electrical and Electronic Engineers, Inc. (New York, NY): pp. 348-351; 1977. (7 refs)

The design and application of noninterfering microprobes for measuring the temperature of materials exposed to electromagnetic fields are described. A cholesteric crystal probe, which operates over a temperature range of 10-40 C has been developed, but this type of probe requires recalibration due to liquid crystal aging and instability. A dielectric microthermometer has been developed and operates over a temperature range of -40 C to +150 C in steps of 40 C. The principle of operation involves the reflection of a light beam on a thermodilatable liquid contained in a small capillary glass pipe. Measurements over frequency ranges of 900-915 MHz, 2,400-2,500 MHz, and 8.2-12.4 GHz reveal that perturbation caused by the thermometer is very low (less than or equal to 0.1 dB), regardless of the orientation of the probe in relation to the electric field. The standing wave ratio of the probe is less than 1.1:1. Experiments have been run in which the microwave thawing process of chopped beef was recorded over a temperature range of -30 C to +20 C. These experiments indicate that the microwave thawing process can be continuously recorded. The sensitivity of the probe is about 0.5 C, and the probe response time is less than 15 sec. The probe should be useful for local dosimetry applications, studying electromagnetic energy penetration and absorption by biological media, and many other medical and industrial applications.

5174 THE DESIGN AND PERFORMANCE OF A CIRCULARLY POLARIZED DIRECT CONTACT APPLICATOR FOR MICROWAVE DIATHERMY. *(Eng.)* Kantor, G.; Witters, D. M.; Greiser, J. W. *In: 1977 IEEE MTT-S International Microwave Symposium held in San Diego, CA on June 21-23, 1977.* Inst. Electrical and Electronic Engineers, Inc. (New York, NY): pp. 364-367; 1977. (2 refs)

A circularly polarized direct contact applicator for microwave diathermy is described. The applicator is a circularly polarized conical horn operating at a frequency of 2.45 GHz with a far field beamwidth of 55.5 degrees and a maximum input power capability of 300 W. The design consists of a circular waveguide fed with a coaxial probe, two sets of posts placed in the guide at 45 degrees to the input probe to generate a circularly polarized field, and a resistive card at the input end of the horn to minimize mismatch while applied to human tissue. The design includes a microwave choke around the output aperture to suppress leakage. The performance of the applicator was evaluated by mapping the near field at 5 mm from the aperture. The heating pattern in planar phantoms of simulated fat and muscle tissue was symmetrical, with a maximum value of 15.7 mW/cm^2 per W of forward power at the center and a minimum of about 0.2 mW/cm^2 per W of forward power at its periphery. Impedance matching data revealed a standing wave ratio of less than 2.1:1 at four locations on the back of a person and for free space radiation. Thermographic analysis of the microwave heating of a planar phantom revealed that the width of the heating pattern (defined as the width of the trace for which the temperature rise is half the maximum temperature rise) was 7.5 cm and the depth of penetration (defined as the distance between the fat-muscle interface and the depth at which the temperature decreased by 50% with respect to the maximum) was 2.2 cm for the symmetrical case where the center of the applicator was directly above the phantom midplane. For the case where the center of the aperture was moved 3.81 cm from the separation midplane along the z-axis, the corresponding width

and depth values were 7.0 cm and 2.0 cm, respectively. The relatively large values of heating pattern width suggest uniform heating in the center of the heating pattern. Maximum leakage for direct contact loading (applicator on top of a planar phantom) was 0.8 mW/cm^2 per 100 W of forward power.

5175 A SYSTEM FOR DEVELOPING MICROWAVE INDUCED HYPERTHERMIA IN SMALL ANIMALS. *(Eng.)*
Baker, R. J.; Smith, V.; Phillips, T. L.; Kobe, L.; Kane, L. *In: Digest of 1977 IEEE MTT-S International Microwave Symposium held in San Diego, CA on June 21-23, 1977.* Inst. Electrical and Electronic Engineers, Inc. (New York, NY): pp.360-363; 1977. (18 refs)

A system for developing microwave-induced hyperthermia in small animals is described. The waveguide components include a conventional WR-650 coax-to-waveguide adapter; an electrically compensated one dimension transition section, which tapers to a reduced height test section; and a reduced height coax-to-waveguide adapter, which is followed by a coaxial dummy load. The test animal is placed in a plastic test tube, which is inserted in a 1-inch diameter hole centered in the broad face of the waveguide. A frequency of 1,210 MHz produces maximum energy absorption in the test animal. Thermographic studies of sacrificed sectioned mice heated in the applicator revealed deep heating and preferential heating in the center of the animal. The preferential heating was also seen in mouse phantoms (agar and sodium chloride). In an initial trial where anesthetized mice were heated at either 40 C for 25 min or 43 C for 15 min, one LAF_1 mouse died 16 hr postheating to 43 C in the abdominal region, while the remaining mice (Balb/C strain) survived lesser times. In a second trial, the anesthetic dose was reduced (60 mg/kg Diabutal), and two thermistors in different anatomic positions were used to monitor temperature. One thermistor was inserted into the rectum (final position being mid-abdomen), and the second thermistor was implanted subcutaneously, with its position being mid-height in the waveguide (as was the rectal thermistor). Rotation of the test tube containing the mouse revealed that the subcutaneous thermistor reading was essentially independent of angular orientation (near microwave generator or near load) and that the reading was consistently 1-2 C warmer than the rectal thermistor. All of five Balb/C mice heated to 40 C, as indicated by the subcutaneous thermistor, over periods of 15-45 min are alive and appear healthy at 5 days postheating.

5176 EFFECT OF SURFACE COOLING AND BLOOD FLOW ON THE ELECTROMAGNETIC HEATING OF TISSUE. *(Eng.)* Kritikos, H. N.; Foster, K. R.; Schwan, H. P. *In: Digest of 1977 IEEE MTT-S International Microwave Symposium held in San Diego, CA on June 21-23, 1977.* Inst. Electrical and Electronic Engineers, Inc. (New York, NY): pp. 354-356; 1977. (8 refs)

Temperature profiles are calculated in tissue models exposed to microwave radiation by solving the heat transport equation and taking into account thermal conduction, thermal convection due to blood flow, and surface cooling of the tissue. Two idealized models representing limiting cases of the microwave heating behavior of actual tissue sections are considered. The first consists of a semi-infinite tissue slab exposed to plane electromagnetic radiation, and the second considers focused microwave heating in a finite volume of tissue. In both cases, the steady state temperature profile is largely determined by the blood flow; the effective heating depth can be much larger than the energy penetration depth in tissue, an effect particularly noticeable for 10 GHz radiation. In the steady state, the blood flow at physiologic levels creates an effective thermal diffusion length of 1-2 cm, which leads to an effective averaging of microwave heating patterns over distances of this magnitude. To some extent, this effect will reduce the non-uniform tissue heating due to hot spots and also the ability to focus the microwave heating to specific regions in the tissue by external means. The results also imply that microwave irradiation at the generally recognized safe level of 10 mW/cm^2 is not likely to increase tissue temperature by more than 0.5 C.

5177 MEASUREMENTS OF 1.8-2.7-GHZ MICROWAVE ATTENUATION IN THE HUMAN TORSO. *(Eng.)*
Yamaura, I. (Electrotechnical Lab., 5-4-1 Mukodai-cho, Tanashi-shi, Tokyo, Japan). *IEEE Trans Microwave Theory Techniques* 25(8): 707-710; 1977. (8 refs)

Measurements of 1.8-2.7 GHz microwave attenuation in the human torso are reported. Sweep-frequency measurements indicated that leakage effects were the most troublesome measurement problem. To minimize these leakage effects, close coupling between the antenna and the body was maintained using flanged aperture antennas as the transmitting and receiving antennas. Power at the receiving antenna was recorded over a frequency range of 1.8 to 2.7 GHz, with the maximum power density on the human subject about 0.5 mW/cm^2. Attenuation constants for the abdomen and the left thorax were about the same as those for muscle tissues. Changes in attenuation caused by heartbeats or respiration were observed for the left thorax. The attenuation constant of the right thorax was smaller than that for muscle but much larger than that of fat, implying that the attenuation in the right thorax is mainly caused by lung tissues. It was estimated that the close-coupling condition has over a 10-dB margin for leakage at a frequency of 2 GHz.

5178 EFFECT OF SUPER-HIGH FREQUENCY ELECTROMAGNETIC IRRADIATION ON THE ELECTROPHORETIC MOBILITY OF ERYTHROCYTES. *(Rus.)* Ismailov, E. Sh. (Dagestan Polytechnical Inst., Makhachkala, USSR). *Biofizika* 22(3): 493-498; 1977. (14 refs)

The effect of irradiation (1,009 MHz, intensity 2-45 mW/cm^3, duration 4, 8, or 15 min) on the electrophoretic mobility (EM) of human erythrocytes

was studied in vitro at 37 C immediately or 10-90 min after irradiation. Immediately after irradiation at an intensity of 45 mA/cm^3 for 4, 8, and 15 min, the EM (in 10^{-4} cm/V/sec) was 1.20, 1.30 and 1.38, respectively, compared with 1.28-1.33 in the control. The EM was highest 30 min after the irradiation and reduced comparatively with the initial values after 70 min (1.32, 1.28, and 1.25, respectively). The EM, measured immediately after irradiation for 30 min at the intensities of 2, 5, 10, and 20 mA/cm^3 was 1.20, 1.12, 1.26, and 1.34, respectively. The highest values were measured 30 min after irradiation. The EM was 1.32 after 80 min irradiation at 10 mA/cm^3 and after 90 min irradiation at 20 mA/cm^3. The changes in the EM are due to the deformation of the double electric layer and to the structural rearrangement of the erythrocyte membrane as a consequence of the phase transition of the structured water in the membrane into a more liquid state. The changes in the EM are reversible.

5179 HEAT-DISSIPATION RATE OF MICE AFTER MICROWAVE IRRADIATION. *(Eng.)* Ho, H. S. (U. S. Dept. Health, Education, and Welfare, Public Health Service, Food and Drug Admin., Bureau Radiological Health, 5600 Fishers Lane, Rockville, MD 20852); Mc Manaway, M. *J Microwave Power* 12(1): 93-100; 1977. (10 refs)

The heat dissipation rate from individual CF1 male mice before and after microwave irradiation was determined with a biocalorimeter. The mice were irradiated singly in an environmentally-controlled waveguide apparatus (24 C temperature and 50% relative humidity) with 2,450 MHz continuous wave microwave radiation. Incident power levels of 0 (sham), 0.4, 0.8, 1.7, and 3.3 W resulted in corresponding mean average absorbed dose rates of 0, 7, 12, 27, and 39 mW/g. An increased heat dissipation rate in comparison with sham-irradiated mice was observed for mice receiving average absorbed dose rates of 12 mW/g or more.

5180 EFFECT OF HIGH FREQUENCY RADIATION ON THE TANNING PROCESS IN THE COLEOPTERA *TENEBRIO MOLITOR*. *(Fre.)* Tchao, Y. H. (Laboratoire d'opto-acousto-electronique de Valenchiennes, Laboratoire associe au C.N.R.S., 59300 Valenciennes, France); Huet, C.; Lenoir-Rousseaux, J. J. *C R Acad Sci [D] (Paris)* 284(16): 1589-1592; 1977. (10 refs)

High frequency radiation allows blocking of enzymatic reactions controlling metabolic processes. The technique was used to study cuticular tanning of the insect Coleoptera *Tenebrio molitor* as it underwent transformation from the pupal to imago stage, a process under the control of the hormone, bursicon. A total of 170 nymphs, of both sexes and without apparent malformations, were irradiated individually from a high frequency (9,300 MHz) source. An adaptor impedance minimized reflected power to less than 40db of the incident power, and an attenuator and commutator measured power and duration of radiation. After radiation, insects were placed in individual boxes at elevated temperatures.

5181 ON THE INTERDEPENDENCE OF THERMAL AND ELECTROMAGNETIC EFFECTS IN THE RESPONSE OF *BACILLUS SUBTILIS* SPORES TO MICROWAVE EXPOSURE. *(Eng.)* Wayland, J. R. (Sandia Lab., Albuquerque, NM 87115); Brannen, J. P.; Morris, M. E. *Radiat Res* 71(1): 251-258; 1977. (4 refs)

Spores of *Bacillus subtilis* were inactivated in a microwave field at a frequency of 2,450 ± 50 MHz at power levels of up to 30 kW, and the inactivation rates were compared with those obtained by exposure to heat alone in an effort to distinguish the thermal interdependency of electromagnetic effects. The spore samples were exposed in the center of a WG-340 waveguide operating in the transverse electromagnetic$_{10}$ mode to produce as uniform an electric field as practicable. At electric fields of 9, 15, 20, and 30 kW, the inactivation rates (min^{-1}) were 0.00132 ± 0.00036, 0.0754 ± 0.0237, 0.7314 ± 0.0077, and 1.06 ± 0.083, respectively; the corresponding spore temperatures at these inactivation rates and power levels were: 103 ± 4, 120 ± 4, 136 ± 7, and 170 ± 9 C, respectively. When spores were exposed to heat alone at temperatures of 105, 120, and 135 C, the inactivation rates were 0.0251 ± 0.0026, 0.0973 ± 0.0058, and 0.254 ± 0.011, respectively. These results suggest a strong interdependence of thermal and electromagnetic effects based on the difference in the inactivation rates. The differences are a clear indication of a nonthermal microwave effect.

5182 LOCAL TUMOR HYPERTHERMIA IN COMBINATION WITH RADIATION THERAPY. I. MALIGNANT CUTANEOUS LESIONS. *(Eng.)* Kim, J. H. (Dept. Radiation Therapy, Memorial Sloan-Kettering Cancer Center, New York, NY 10016); Hahn, E. W.; Tokita, N.; Nisce, L. Z. *Cancer* 40(1): 161-169; 1977. (25 refs)

The use of local tumor hyperthermia (43.5 C) in combination with radiation therapy (electron or photon beam irradiation) for the treatment of 36 patients with multiple cutaneous malignant lesions (mycosis fungoides, Kaposi sarcoma, malignant melanoma, lymphoma cutis, synovial sarcoma, squamous cell carcinoma, sweat gland carcinoma, and rectal carcinoma metastatic to the skin) is reported. Hyperthermia was produced by either wet heat or radiofrequency (27.12 MHz) inductive heating using a modified diathermy unit. In general, initial tumor regression rates were faster in patients treated with radiation plus hyperthermia than in patients treated with radiation alone, particularly in patients with Kaposi sarcoma and lymphoma cutis. Among 26 patients receiving combination therapy, 10 had a recurrence, with seven of these showing an improved disease-free interval. Among five patients receiving fractionated (twice/wk) hyperthermia (radiofrequency heating) alone, complete regressions were observed in one patient receiving 45 min of