between 0.915 and 2.45 GHz, frequencies for which commercial microwave heating equipment is available and which have been shown to be useful for organ thawing. The microwave signal was 100% square wave modulated external to the source. Although the data showed certain similarities in the general temperature dependencies of the microwave properties of DMSO, EG, and GCL, different characteristics were clearly present in each. At approximately 1.5 GHz, DMSO was by far the most electrically active, exhibiting a room temperature dielectric constant almost four times larger than that of EG and almost 10 times that of GLC. However, at low temperatures, the dielectric constant of DMSO was only approximately two times that of EG and GLC. A comparison of loss tangent versus temperature curves showed that all three cryoprotective agents have maximum loss tangent values of approximately the same magnitude. However, there was a great variation as to where in the temperature range the maxima occurred. The highest loss tangent for GLC was at approximately room temperature, with GLC rapidly losing its lossiness with declining temperature. In contrast, EG was quite lossy over a fairly wide temperature range; the loss tangent showed a modified plateau from approximately +5 C to about -10 C, and it gently decreased at both above and below this temperature range. The loss tangent of EG fell to an extremely low value below -60 C, a value that was less than one fourth as small as that for GLC's low temperature minimum. A wide temperature range of relatively high loss tangent values was exhibited by DMSO, but below the temperature of about -40 C this property fell off very rapidly with decreasing temperature. This decrease was about twice as fast as that for EG. From the above data it appears that, by properly designing a cryoprotective mixture, electrical property temperature dependence may be controlled. Due to the frequency dependence of both the dielectric constant and the loss tangent, the reported results are only truly valid for frequencies approximating 1.5 GHz.

6064 SOFT TISSUE STRETCHING WITH MAGNETS. *(Eng.)* Engel, J. (Chaim Sheba Medical Center, Tel Hashomer and Tel-Aviv Univ., Sackler Sch. Medicine, Israel); Dagan, J. *Hand* 10(3): 312-316; 1978. (2 refs)

The possibility of stretching soft tissues by magnetic force was tested in rabbits and dogs. A small ferromagnetic metallic sphere was implanted under the skin of the animal's amputated forearm, and a Samarium Cobalt permanent magnet (residual induction of 8,000 G and coercive force of 7,500 Oe) that was connected to a turnbuckle device was attached to the stump by means of two Kirschner wires. This device stretched the skin by pulling the implanted sphere toward the magnet. The goal was to elongate the stump by 2-3 cm. The device was activated once a day, achieving a stretch of 3-4 mm daily. Initially, experiments were performed on the amputated forearm of a rabbit, but these failed because the rabbit did not tolerate the bulky apparatus connected to the stump. A second series of experiments was performed on four mongrel dogs whose upper limbs were amputated through the forearm. A metallic disc was inserted, and the stump was closed. The turnbuckle device containing the magnets was mounted on the leg and transfixed to the forearm bone by means of two Kirschner wires proximal to the magnet at the stump. X-ray films demonstrated that the metallic disc tilted after application of the magnet, causing the skin wound to break down. Ten additional dogs were amputated in the same manner, but this time a metal sphere, rather than a disc, was implanted distal to the bone. The sphere was installed under the skin in five dogs. However, the metal sphere caused the skin to break in these dogs between days 2 and 5 after stretching was initiated. In another five dogs the sphere was covered by muscle and skin. In these dogs, migration of the metal sphere was much slower than in the first group of five dogs; however, elongation was achieved without skin necrosis or breakage. The optimal distance between the magnet and metal sphere was that which exerted maximal pull but did not cause the skin to blanch or become necrotic. Although no more than 700 g of pull could be exerted without the skin showing signs of impending necrosis, this pull was enough to create a gradual elongation in soft tissue that ranged from 2.4-2.7 mm/day in the mongrel dogs. Vessels and nerves were not affected in the test animals.

6065 SINGLE NEURON ANALYSIS OF THE HUMAN MIDBRAIN TEGMENTUM: ROSTRAL MESENCEPHALIC RETICULOTOMY FOR PAIN RELIEF. *(Eng.)* Amano, K. (Neurological Inst., Tokyo Women's Medical Coll., 10 Kawada-cho Shinjuku-ku, Tokyo, Japan); Tanikawa, T.; Iseki, H.; Kawabatake, H.; Notani, M.; Kawamura, H.; Kitamura, K. *Appl Neurophysiol* 41(1/4): 66-78; 1978. (19 refs)

Microelectrode recordings from nociceptive neurons in the human midbrain reticular formation (MRF) were made during rostral mesencephalic reticulotomy (RMR) for pain relief in four patients. The target area was in the MRF bordering the periaqueductal gray matter at the superior collocular level. The recording loci of single neuron discharge and stereotactic radio frequency lesion were 13-16 mm posterior to the midpoint of the AC-PC line and 508 mm below the AC-PC line. The laterality of the target was measured from the center of the aqueduct, ranging from 5-8 mm from the midline. Single neuron analysis of MRF investigated in four patients with intractible pain during RMR revealed the following: abrupt change of background noise on entering the reticular formation; firing of neurons mostly composed of small cells; bilateral projection from the periphery with wide receptive fields; and a predominance of delayed firing in response to peripheral pinprick stimulation. The unit latency of these nociceptive neurons was classified into three groups: in the range of less than 250 msec (early response type); in the range of 400-800 msec (intermediate type); and in the range of more than 1,000 msec (delayed response type). Electrical stimulation of MRF

(3-10 V, 60 Hz, 1 msec pulse width) produced pain sensation mainly in the face but also in the trunk and extremities contralateral to the side of stimulation. This sensory phenomenon by electrical stimulation was seen when the electrode was in the reticular formation, more than 5 mm off the midline of the aqueduct. When the stimulating electrode was more medial in the central gray matter, the patient expressed fear sensation and experienced a burning sensation of the entire body rather than pain. A small radio frequency lesion in the MRF (approximately 2 by 3 mm) produced marked relief of pain. The stereotactic lesion is considered to be in the rostral MRF, lateral to fasciculus Foreli dorsolateralis and dorsolateral to the central tegmental tract and medial longitudinal fasciculus. A small radio frequency lesion in MRF has therapeutic significance in the treatment of intractable pain by making stereotactic intervention in the dividing zone of the ascending extralemniscal system at the midbrain into two different pathways, one being the projection to the posterior thalamus as discriminative pain or pain as sensation and the other to the limbic emotional brain as motivational pain or pain as suffering.

6066 THE EFFECTS ON CARDIAC PACEMAKERS OF IONIZING RADIATION AND ELECTROMAGNETIC INTERFERENCE FROM RADIOTHERAPY MACHINES. *(Eng.)* Marbach, J. R. (Radiotherapy Service, Veterans Admin. Hosp., 2002 Holcombe Blvd., Houston, TX 77211); Meoz-Mendez, R. T.; Huffman, J. K.; Hudgins, P. T.; Almond, P. R. *Int J Radiat Oncol Biol Phys* 4(11/12): 1055-1058; 1978. (2 refs)

Four demand-type pacemakers were exposed to electromagnetic fields associated with two betatron units and three linear accelerators. The pacemakers tested were the medtronics Models 5944 and 5950, the Cardiac Pacemakers Model 0502 Minilith, and the Intermedics Model C-MOS I. To simulate patient implant conditions, the pacers were placed in a 0.2% saline bath and fastened loosely to a block of lucite with a rubber band. The water temperature was maintained between 31 and 37 C since pulse rates vary with temperature. In each instance, from 1-2.5 cm of saline covered the pacer. With the exception of the Medtronics 5950 unit, which appeared to function normally in a Siemens electron beam, all the pacers failed under both betatron units. Failure was due to either loss of inhibit function, which is believed to be caused by the magnetic field of the machine, or erratic output, which is believed to be caused by the electric field from the beam injector. All of the pacers functioned normally under exposure to the three linear accelerators with the exception of the Minilith 0502, which failed completely while under an ARCO 8 beam. It also failed when the pacer was located out of the beam toward the machine gantry. In each case where failure from electromagnetic interference was encountered, the pacers returned to normal function immediately after the electromagnetic fields were removed. It is concluded that the use of betatrons should be avoided in patients who have implanted cardiac pacemakers. When linear accelerators are used, each case should be considered individually since variations from one therapy unit to another can play a very important role in the type of interference exerted on the pacemaker.

6067 MICROWAVE INTERROGATION OF DIELECTRIC TARGETS. PART I: BY SCATTERING PARAMETERS. *(Eng.)* Larsen, L. E. (Dept. Microwave Res., Walter Reed Army Inst. Res., Washington, DC 20012); Jacobi, J. H. *Med Phys* 5(6): 500-508; 1978. (51 refs)

A system for the generation of microwave images from homogeneous and heterogeneous dielectric targets is described. The microwave imaging system is based on automatic microwave network analysis for scattering parameters using launched radiation. Small dielectric targets may be imaged in water-dominated environments with dielectrically loaded and matched transmitting and receiving antennas. Targets on the order of 1 cm may be imaged with radiation of free space wavelength on the order of 10 cm by this technique. Geometrical fidelity can be retained in the near field for simple targets when multipath is well controlled. Small physical apertures improve spatial resolution. The method is sensitive to changes of the innermost dielectric in multilayered targets. The method may be generalized to three-dimensional analysis, which does not require prior knowledge of propagators (in contrast with Fourier transform holography). The radiation levels necessary for such interrogation in biomedical targets are well below the present ANSI C95 advisory standard.

6068 MICROWAVE INTERROGATION OF DIELECTRIC TARGETS. PART II: BY MICROWAVE TIME DELAY SPECTROSCOPY. *(Eng.)* Jacobi, J. H. (Dept. Microwave Res., Walter Reed Army Inst. Res., Washington, DC 20012); Larsen, L. E. *Med Phys* 5(6): 509-513; 1978. (8 refs)

A microwave time delay spectrometry (MTDS) system that provides unambiguous information for a wide range of time delays and provides discrimination between multiple paths whose differential propagation time is quite small is described. The data from this MTDS system do not become ambiguous until the total propagation time is equivalent to that of over 1,400 miles in free space. This is clearly adequate for biologically relevant targets. Additionally, the system as it exists is capable of discriminating between two ray paths whose differential time delay is on the order of 100 picosec. This differential delay corresponds to a differential path length in the brain on the order of 6 mm. In muscle, this would correspond to about 4.5 mm. It has been further demonstrated that the success of such an imaging system depends critically on the physical aperture of the interrogating antennas. As aperture size increases, the inability of the target to occlude the direct ray path renders the system insensitive to small tar-

gets and is thus of diminished value. The water-loaded antennas do have small enough apertures that, when operating in the near field, propagation time may be measured over a region consistent with an imaging application. This approach offers promise for further development to allow later tomographic reconstruction by allowing multipath discrimination. It is clear that the MTDS system has much to offer in solving the temporal and spatial averaging problems encountered by the single-frequency continuous wave measurement systems.

6069 STEREOTACTIC RADIOFREQUENCY HYPOPHYSECTOMY. *(Eng.)* Zervas, N. T. (Dept. Neurological Surgery, Massachusetts General Hosp., Boston, MA 02114); Hamlin, H. *Appl Neurophysiol* 41(1/4): 219-222; 1978. (6 refs)

The use of stereotactic radio frequency (RF) hypophysectomy for the treatment of various disorders is discussed. The RF procedure uses the precise Todd-Wells cephalic instrument to direct a plastic-sheathed electrode (1.7 mm in diameter) containing a thermocouple within its tip intrasellar through either nasal cavity. The electrode slides inside a fitted cannula that has a side outlet at its active end that permits extrusion of a stainless steel spring into a 90 degree arc from its axis. The RF current is used to induce heat within a 4-6 mm length of tissue around a curved spring that ultimately forms a coalescent sequence of elipsoid destructions. The parameters of the RF procedure are a frequency of 1 Hz, a current of 100-300 mA, and a voltage of 20-50 V. Each heat spot is generated by maintaining the electrode tip at 80-85 C for 60-120 sec. The technical steps must be performed in sequence and with detail to provide safety while achieving maximal inactivation of the adenohypophysis. Among a recent series of 100 successive patients treated with the RF technique, cerebrospinal fluid leakage developed only once and was successfully countered by 6 days of regulated lumbar spinal drainage. There was no instance of visual or oculomotor deficit. Overall operative mortality was less than 1%. Among 116 cases of diabetic retinopathy treated by the RF technique, 80% achieved lasting improvement or stabilization of vision, and many have lived beyond 10 yr. The largest group of patients treated by the RF technique comprised metastatic breast cancer patients, with the usual candidate having skeletal and often multiorgan metastases as well as being postmenopausal, ovariectomized, estrogen-androgen responsive, and recently reactive to an estradiol receptor test. Success (1-3 yr survival) was obtained in approximately 55% of these patients. Many patients achieved rapid pain relief. The RF procedure has also been applied in several cases of active acromegaly due to small subdiaphragmatic tumors and also in a few craniopharyngiomas. Approximately 80-85% of all patients tested showed significantly diminished levels of growth hormone production. The RF procedure is not suitable for larger tumors or for isolated microadenoma, which is usually associated with persistent prolactic secretion.

6070 ELECTRICAL SPINAL CORD STIMULATION FOR SPASTIC MOVEMENT DISORDERS. *(Eng.)* Siegfried, J. (Dept. Neurology, Univ. Zurich, Zurich, Switzerland); Krainick, J.-U.; Haas, H.; Adorjani, C.; Meyer, M.; Thoden, U. *Appl Neurophysiol* 41 (1/4): 134-141; 1978. (12 refs)

The results of using electrical spinal cord stimulation for the treatment of 10 patients (8 men and 2 women; ages, 32-61 yr) with various spastic disorders are reported. The H reflex was conditioned by a dorsal column stimulus train (1-300 msec, 70 Hz and 0.2 msec impulse duration). In all patients stimulation of the cord elicited paresthesias in the implanted cervical or thoracic segment and, with higher intensities, in both legs or in all four extremities. Shortly after a few minutes of stimulation, the patients reported a decrease in the feeling of muscular stiffness. Neurologic examination confirmed this decrease of hypertonicity for periods ranging from 1-12 hr. The best results were observed in cases of multiple sclerosis (six patients). Two cases of spastic paraplegia as well as a case of vascular lesion of the cord were moderately improved. A post-traumatic patient with an almost complete interruption of the cord at the C_5 level showed very little improvement of a very severe tetraspasticity. The physiologic mechanisms of dorsal cord stimulation on spasticity are not yet determined since it is not known what is being stimulated.

6071 BEHAVIORAL EFFECTS OF MICROWAVE IRRADIATION ON SQUIRREL MONKEY *(SAIMIRI SCIUREUS)* PERFORMANCE OF A REPEATED ACQUISITION TASK. *(Eng.)* Nelson, T. D. (Naval Aerospace Medical Res. Lab., Pensacola, FL 32508). 18 pp.; 1978. [available through National Technical Information Service, Springfield, VA 22161, Document No. AD A055 953/4GA]. (9 refs)

The effects of pulsed microwave irradiation on the acquisition of new behaviors were studied in six individually caged male squirrel monkeys *(Saimiri sciureus)* using a repeated acquisition task. For 30-min periods the monkeys were repeatedly exposed to 5.62-GHz microwaves pulsed at a repetition rate of 600/sec. Pulse widths were 0.5 μsec at an average incident power density of 11 mW/cm^2 and 2 μsec at 43 and 53 mW/cm^2. A waveguide connected to a standard gain horn was used to irradiate the monkey's ventral surface while it was restrained in an upright seated position in a Styrofoam restraint chair. Response acquisition was impaired following 30 min of exposure to an incident power density of 53 mW/cm^2 but not to 11 or 43 mW/cm^2. A mean increase of 1.9 C in rectal temperature above control levels accompanied the behavioral effects observed in monkeys irradiated at a power density of 53 mW/cm^2. No such effects were observed without concomitant hyperthermia. These effects were transitory, and no evidence of irreversible impairment of learning ability was observed. The threshold power density necessary to significantly disrupt behavior under the conditions of this experiment was estimated to be be-

tween 45 and 50 mW/cm^2. This value compares to an estimated threshold for behavioral effects in the squirrel monkey of between 40 and 50 mW/cm^2 for 60 min of exposure to continuous wave 2,450-MHz microwaves. The results of this experiment were compatible with the hypothesis that behavioral changes were directly related to hyperthermia in the monkey.

6072 EFFECTS OF INTERSTITIAL IRRADIATION ALONE, OR IN COMBINATION WITH LOCALIZED HYPERTHERMIA ON THE RESPONSE OF A MOUSE MAMMARY TUMOR. *(Eng.)* Miller, R. C. (Div. Radiation Oncology, Dept. Radiology, Univ. Arizona Health Sciences Center, Tucson, AZ 85724); Leith, J. T.; Veomett, R. C.; Gerner, E. W. *J Radiat Res (Tokyo)* 19(3): 175-180; 1978. (20 refs)

The effects of interstitial irradiation (^{226}radium) alone or in combination with localized radio frequency (500 kHz) hyperthermia on the growth of a transplantable mammary sarcoma (EMT_6) in the mouse were investigated. For irradiation, tumors about 45 mm^3 in volume were implanted with two 3-cm long needles containing ^{226}radium; computerized dosimetry calculations indicated that the tumor was enclosed by an isodose curve of about 40 rad/hr at its periphery. For combined hyperthermic treatments, the implanted radium needles were used as electrodes for radio frequency heating (43 C for 1 hr). Localized hyperthermia in combination with interstitial irradiation resulted in a tumor volume reduction of more than 60% by 4 days after the initiation of treatment, whereas either hyperthermia or irradiation alone resulted in only a 20% reduction in tumor volume. Overall, there was a large killing effect on hypoxic and nutritionally deprived cells, leading to rapid cytolysis and a marked decrease in tumor volume that occurred as early as 1 day after combined hyperthermia and interstitial irradiation was initiated. Since the cell yield per milligram of tumor showed no difference for either treatment, while the tumor volume was reduced by up to 60% for the combined treatment, it is concluded that the actual cell survival must have been greatly reduced after combined treatment compared to irradiation alone. The implication is that a large percentage of hypoxic cells are preferentially removed by the combined modality treatment. It is concluded that these initial results provide a rationale for the use of hyperthermia combined with interstitial irradiation in the treatment of human cancers, particularly those of the head and neck.

6073 MICROWAVE-INDUCED INJURIOUS EFFECTS ON THE HUMAN-EMBRYO IN UTERO. *(Eng.)* Neelakantaswamy, P. S. (Electronics Section, Sch. Applied Sciences, Univ. Science Malaysia, Minden, Penang, Malaysia). *Biomed Tech* 23(11): 263-269; 1978. (17 refs)

A damage-risk criterion is established for the growing human-embryo in utero that is exposed to microwave radiation. Based on assumptions dealing with changes in oxygen consumption in the intrauterine region that is susceptible to microwave-induced damage, the relative time of failure for different stages of gestation is mathematically evaluated. It is evident that the risk of damage is more significant for the early stages of fetal growth. The dependency of oxygen consumption on microwave-induced thermal processes in the fetus is established and quantified in terms of a fatal factor. As a measure of the hazard involved, a term "lethality" is defined and evaluated in terms of deterministic parameters. Thus, the concepts of risk and damage are given concrete numeric expressions that can be extended to other susceptible parts of the body that are subjected to microwave irradiation.

6074 MICROWAVE DIELECTRIC RELAXATION OF AQUEOUS SOLUTIONS OF DEXTRAN. *(Eng.)* Delbos, G. (Laboratoire d'Optique Ultra-Hertzienne, Universite de Bordeaux 1, 351 cours de la Liberation, 33405 Talence Cedex, France); Bottreau, A.-M.; Marzat, C.; Salefran, J.-L. *J Microwave Power* 13(1): 69-75; 1978. (5 refs)

Microwave dielectric relaxation of aqueous solutions of T 110 dextran (average molecular weight of 1.1 x 10^5) was studied. Measurements were performed at the following frequencies: 3.624, 9.455, 15.350, and 35.250 GHz. A resonant cavity method was used at the first three frequencies, while an interferometric method was used at 35.250 GHz. The concentrations of the aqueous dextran solutions were 50, 100, 200, 300 and 400 g/l. Measurements were carried out at different temperatures between 10 and 60 C. A two "Debye" decomposition did not provide good agreement between experimental results and calculated values. However, good agreement between experimental results and calculated values was obtained using the Cole-Cole model with a distribution of relaxation times. The relaxation time distribution increased with concentration and temperature. It is concluded that the dielectric relaxation of dextran's aqueous solutions appears to be due only to the water, which is modified by dextran.

6075 SPINAL CORD STEREOTACTIC TECHNIQUES RE TRIGEMINAL NUCLEOTOMY AND EXTRALEMNISCAL MYELOTOMY. *(Eng.)* Schvarcz, J. R. (Inst. Neurosurgery, Sch. Medicine, Univ. Buenos Aires, Buenos Aires, Argentina). *Appl Neurophysiol* 41(1/4): 99-112; 1978. (53 refs)

The use of spinal cord stereotactic techniques for relieving various types of pain is reported. Radio frequency lesions were placed either at the spinal trigeminal nucleus (stereotactic trigeminal nucleotomy) or at the central cord region (stereotactic extralemniscal myelotomy) to interrupt preferentially multisynaptic nonspecific pathways. A total of 104 stereotactic trigeminal nucleotomies were performed on 100 patients. Among 48 patients with central pain from benign conditions, abolition of hyperpathia and marked reduction or disap-

pearance of deep background pain was achieved in 87.5% of those with postherpetic neuralgias, in 57% of those with anesthesiae dolorosa, and in 72% of those with dysesthesic conditions. The follow-up period ranged from 0.5-5.5 yr. Another 21 patients had idiopathic facial neuralgias; however, at this time, percutaneous thermocontrolled differential rhizotomy seems to be the procedure of choice for idiopathic trigeminal neuralgia. Among 31 patients with pain from malignancies, satisfactory pain relief was obtained in 83.8% of the cases after trigeminal nucleotomy, with the follow-up period ranging from 2-30 mo. A total of 76 myelotomies were performed on 75 patients. Among 14 patients with pain of central origin from benign conditions (4 causalgias, 4 postherpetic neuralgias, 3 brachial plexus avulsions, and 3 spinal cord lesions), abolition of hyperpathia and disappearance or marked reduction in deep background pain was achieved in 64% of the cases. The follow-up period ranged from 0.5-4 yr. Extralemniscal myelotomy was also performed in 61 patients with pain related to neoplasms; 42 had lower body, midline, and/or bilateral pain (mostly from rectal or cervical carcinomas) and 19 patients had unilateral upper body pain (mostly from lung carcinomas with respiratory inadequacy). Satisfactory pain relief was obtained in 78% of the cases. The follow-up time ranged from 0.5-24 mo, but 81% of the patients died within the first 6 mo. There were no lasting side effects associated with the stereotactic technique.

6076 IONIC FACTORS IN RELEASE OF $^{45}Ca^{2+}$ FROM CHICKEN CEREBRAL TISSUE BY ELECTROMAGNETIC FIELDS. *(Eng.)* Bawin, S. M. (Brain Res. Inst., Univ. California, Los Angeles, CA 90024); Adey, W. R.; Sabbot, I. M. *Proc Natl Acad Sci* 75(12): 6314-6318; 1978. (36 refs)

The effect of radio frequency stimulation (amplitude modulated at brain wave frequencies) on radiolabeled calcium^{+2} (Ca^{+2}) efflux from isolated chicken cerebral tissue was investigated. All irradiations were performed for 20 min in a 450-MHz horn radiator. The radio frequency generator was sinusoidally amplitude-modulated at 16 Hz. The incident field on the tissue was 0.75 mW/cm^2 in most cases. Radio frequency stimulation increased Ca^{+2} efflux from cerebral tissue, and the response was not sensitive to variations in the calcium concentration (0-4.16 mmolar [mM]) in the bathing solution. The radio frequency-induced Ca^{+2} efflux was inhibited in the absence of normal bicarbonate levels (2.4 mM). When the pH of the test solution was lowered from 7.6 to 6.8 by the addition of 0.108 mM hydrogen chloride, the radio frequency-induced Ca^{+2} efflux was enhanced. The presence of 0.5 mM lanthanum chloride in bicarbonate-free solution restored electrical responsiveness but the stimulus decreased (by 7%) rather than increased the efflux of Ca^{+2}; there was also a significant increase in the brain-to-efflux ratio (4.33 ± 0.17) in comparison with controls in bicarbonate-free medium (3.75 ± 0.12). The lanthanum-induced decreases in electrically stimulated Ca^{+2} efflux were of the same order of magnitude at lanthanum concentrations of either 0.5 or 2.0 mM. The results suggest that low-frequency, weak, extracellular electric gradients may be transduced in a specific class of extracellular negative binding sites normally occupied by Ca^{+2} and susceptible to competitive hydrogen ion binding.

6077 MICROWAVE-INDUCED HYPERTHERMIA IN CANCER TREATMENT: APPARATUS AND PRELIMINARY RESULTS. *(Eng.)* Mendecki, J. (Dept. Radiotherapy, Montefiore Hosp. and Medical Center, Bronx, NY 10467); Friedenthal, E.; Botstein, C. *Int J Radiat Oncol Biol Phys* 4(11/12): 1095-1103; 1978. (18 refs)

Experimental and clinical studies on the use of microwave radiation (915 or 2,450 MHz) for inducing hyperthermia (42.5-43 C) in cutaneous and subcutaneous tumors are described. Preliminary experiments were performed with various microwave applicators to determine the power required to raise the temperature of the irradiated volume to the desired threshold of approximately 42.5 C and then to maintain it at this level. In general, a power density of about 1 W/cm^2 of tumor surface area was necessary to operate the applicators effectively. In a pilot experiment using a waveguide applicator filled with a solid dielectric and prematched for muscle tissue, 54 mice with mammary adenocarcinoma received four hyperthermia treatments localized to the tumor site (43 C, 45 min, every other day), while 18 tumor-bearing mice served as controls. Complete eradication of tumors was achieved in all of the treated animals, and they showed no evidence of tumor recurrence over a 4-mo observation period. All of the 18 controls died within 4 wk after tumor inoculation. Clinical trials, which are still in progress, indicated that hyperthermia appears to be beneficial in the treatment of basal cell carcinoma, malignant melanoma, metastatic breast cancer, and local recurrence of breast adenocarcinoma following radical mastectomy. This appears to be especially true when hyperthermia is used in conjunction with ionizing radiation. Based on heat mapping experiments in both simulated body-cavity geometries and in vivo animal measurements, a coaxial applicator appears to have an important potential for the treatment of tumors contained in body cavities. The demonstration of directive heating using this type of applicator makes it particularly useful for the clinical treatment of human malignancies.

6078 FREE-SPACE ELECTRIC FIELD MAPPING OF MICROWAVE DIATHERMY APPLICATORS. *(Eng.)* Witters, D. M., Jr.; Kantor, G. (Div. Electronic Products, Bureau Radiological Health, Food and Drug Admin., Rockville, MD 20857). 25 pp.; 1978. [available through U.S. Dept. HEW, PHS, FDA, BRH, Rockville, MD 20857, HEW Publication (FDA) No. 79-8074]. (6 refs)

Free-space electric field maps are presented for various prototype and clinically used microwave

diathermy applicators that operate at a frequency of 2.45 GHz. Thermal maps describing energy deposition in planar phantoms of simulated tissue also are presented to further confirm the results of the field maps. It is shown that the transverse field induces virtually all of the heating in tissue and that the longitudinal or radial field does not contribute significantly to the heating effect of microwave diathermy. Parameters for the safety and thermal effectiveness of microwave diathermy applicators are also presented. Leakage of electromagnetic radiation from the applicators is higher for the older type B, C, and E free-space applicators than for the more recent Siemens and Transco applicators. The type B applicator is a hemispherical applicator (15.24 cm in diameter) with conical feed. Type C (12.7 cm by 11.43 cm) and the more recent type E (17.15 cm by 13.97 cm) applicators are corner reflectors with different T-shaped feeds. The Siemens applicator is circular (16.51 cm in diameter) with a helical feed. The Transco applicator (15.24 cm in diameter) is a direct contact applicator that is positioned directly on (or within 1 cm of) the tissue to be treated. The applicators' effectiveness was correlated with the ratio of the transverse field to the longitudinal field at the aperture center. Of the applicators mapped, the type B was by far the least effective because of the doughnut-shaped transverse field with a peaked radial field located over the doughnut's center (minimum). The type B applicator therefore has a small value for this ratio compared with the large value for the very effective Transco applicator. For clinical use, the Transco applicator seems to be the safest and most effective in terms of heating the prescribed tissue with low leakage.

6079 LEAKAGE IN THE PROXIMITY OF MICROWAVE DIATHERMY APPLICATORS USED ON HUMANS OR PHANTOM MODELS. *(Eng.)* Bassen, H. I.; Kantor, G.; Ruggera, P. S.; Witters, D. M., Jr. (Div. Electronic Products, Bureau Radiological Health, Food and Drug Admin., Rockville, MD 20857). 16 pp.; 1978. [available through U.S. Dept. HEW, PHS, FDA, BRH, Rockville, MD 20857, HEW Publication (FDA) No. 79-8073]. (4 refs)

Leakage radiation in the proximity of a 2,450-MHz contact microwave diathermy applicator developed for BRH by Transco Products, Incorporated was measured using various human anatomic models (phantoms) and two human volunteers. The objective of the study was to evaluate the practicality of using phantoms to predict leakage that would occur during actual clinical treatment procedures. The human volunteers were minimally exposed over 1-min intervals to low power (1-1.5 W of net power) simulated treatments, while leakage fields were mapped over the entire applicator/body interface surface. From typical diathermy treatments using the applicator on phantoms or humans at low power levels, the leakage at 5 cm from the surface of the applicator/tissue interface was extrapolated to effective treatment conditions (235 W/kg delivered to the phantom muscle material). The leakage levels for the human back, thigh, and elbow treatments were computed to be less than 5 mW/cm^2 under full-power conditions. The leakage for the forearm under full-power conditions was computed to be less than 10 mW/cm^2, while for the upper arm a maximum of 11.9 mW/cm^2 was obtained. These results suggest that the Transco contact applicator is generally appropriate for low-leakage back and thigh treatments. In addition, there was good agreement (within a factor of 2) between virtually all actual leakage data (human) and simulated (phantom) treatments provided that the appropriate phantoms were used. These results can be applied to the proposed BRH microwave diathermy standard, which intentionally omits the use of human subjects for diathermy equipment performance testing. It is concluded that leakage testing with appropriate phantoms is a reasonable means for minimizing unnecessary microwave leakage in clinical conditions. Phantom data on leakage and energy deposition for conventional, non-contact applicators (types B and E) revealed that high leakage (35.5 and 44.0 mW/cm^2) would have occurred under identical effective treatment conditions.

6080 ASSAY OF NOREPINEPHRINE AND DOPAMINE IN THE RAT BRAIN AFTER MICROWAVE IRRADIATION. *(Eng.)* Maruyama, Y. (Section Biochemical Pharmacology, Japan Upjohn Res. Lab., Takasaki, Gunma 370, Japan); Kusaka, M. *Life Sci* 23(15): 1603-1608; 1978. (26 refs)

Regional levels of norepinephrine (NE) and dopamine (DM) were measured by high performance liquid chromatography after rat brain enzyme inactivation by microwave irradiation. These levels were compared with those in brains from rats that were decapitated. Half of the rats sacrificed by microwave irradiation were exposed to 1.3 kW of 2.45-GHz radiation for 5.0 sec (low power), while the rest were exposed to 5 kW of 2.46-GHz radiation for 1.5 sec (high power). Using 350-450 g rats, the brain temperature was elevated to 80 C within 5 sec at 1.3 kW and within 1.5 sec at 5 kW. The order of NE regional levels after microwave irradiation was in accord with that obtained by decapitation. However, higher levels of NE (ng/g) were found in the cerebellum (257 ± 11) and the cortex (307 ± 11) after high power irradiation than after decapitation (214 ± 15 and 264 ± 4, respectively). After low power irradiation, NE levels were reduced in the medulla-pons (387 ± 11) and in the midbrain-thalamus (372 ± 12) in comparison with levels after decapitation (522 ± 20 and 506 ± 29, respectively). The level of DM was significantly increased in at least four regions of the brain after microwave irradiation in comparison with the DM level after decapitation. After high power irradiation the DM levels in the medulla-pons, corpus striatum, hippocampus, and cortex (ng/g) were 42 ± 7, 7,087 ± 286, 77 ± 18, and 473 ± 51, respectively, compared with levels of 25 ± 2, 5,565 ± 222, 25 ± 3, and 207 ± 29, respectively, after decapitation. After low power irradiation, DM levels were significantly increased in the cerebellum, medulla-pons, hippocampus, and cortex in

comparison with levels for decapitated specimens. These results indicate the importance of rapid inactivation of brain enzymes in the study of regional levels of NE and DM in the rat brain.

6081 CHRONIC PALEOCEREBELLAR STIMULATION FOR THE TREATMENT OF NEUROMUSCULAR DISORDERS: FOUR CASE REPORT. *(Eng.)* Manrique, M. (Dept. Neurosurgery, Clinica Puerta de Hierro, Madrid, Spain); Oya, S.; Vaquero, J.; Lozano, A. P.; Herrero, J.; Bravo, G. *Appl Neurophysiol* 41(1/4): 237-247; 1978. (20 refs)

Chronic paleocerebellar electrical stimulation was used to treat two patients with cerebral palsy, one patient with paraplegic spasticity, and one with familial cerebellospinal atrophic disease. Paleocerebellar stimulation was performed through a plate silicone-coated mesh, with four pairs of platinum-disc electrodes affixed, placed anteriorly over the cerebellum through small suboccipital craniectomies. Electrode implantation was performed bilaterally in two patients and on the right side in two patients. Stimulation potentials ranging from 6-10 V at a pulse repetition rate of 20-180 Hz were applied on a 15-min on, 15-min off schedule over periods ranging from 90 min to 7 hr daily. Some improvement was noted in three patients treated with high frequency stimulation (180 Hz); however, one of these suffered seizures after 3 mo of chronic stimulation. In two patients posterior fossa explorations revealed marked meningeal proliferation surrounding the electrodes. Light and electron microscopic examinations of biopsies showed loss of Purkinje cells and gliofibrillar reaction. One patient with spastic dystonia was treated with chronic low frequency stimulation (20 Hz) and showed negligible improvement after 9 mo of stimulation. The results indicate that chronic cerebellar stimulation can improve disturbances of posture and muscle tone in some patients. However, the present results seem less successful than those reported by others. Also, such stimulation techniques should be applied cautiously until more is known about their effects on the cerebellum.

6082 THE POSTEROMEDIAL HYPOTHALAMUS AND PAIN, BEHAVIOR, WITH SPECIAL REFERENCE TO ENDOCRINOLOGICAL FINDINGS. *(Eng.)* Mayanagi, Y. (Dept. Neurosurgery, Univ. Tokyo, Tokyo, Japan); Hori, T.; Sano, K. *Appl Neurophysiol* 41(1/4): 223-231; 1978. (12 refs)

The results of using posteromedial hypothalamotomy for the treatment of patients with aggressive behavioral disorders and patients with intractable pain are reported. After demonstration of the third venticle, a fine concentric bipolar electrode (0.8 mm in outer diameter with an interpolar distance of 0.5 mm) was stereotactically inserted through a frontal burr hole into the target point, which was 2 mm below the midcommissural point and 2 mm lateral from the wall of the third ventricle. High frequency stimulation (50-100 Hz, 10-20 V) with square wave pulses of 1 msec in width usually caused marked sympathetic responses, such as, mydriasis, elevation of blood pressure, increase in pulse rate, or short respiratory arrest followed by hyperpnea or tachypnea. During weak stimulation, (10-20 Hz, 5-10 V), patients often noticed a decrease in pain. When good sympathetic responses were obtained, electrocoagulation with high frequency current was performed using the same electrode. No neurologic deficit was found postoperatively. Among 38 evaluable patients with aggressive behavioral disorders, the procedure was considered to have been effective in 95% of the cases, with satisfactory results being obtained in 84%. Among 20 patients with intractable pain, complete or almost complete pain relief was achieved in 60%, partial relief in 35%, and no relief in 5%. From an endocrinologic viewpoint, the procedure appeared to activate the hypothalamic-hypophyseal axis only temporarily, without causing any serious dysfunction.

6083 TREATMENT OF SPASMODIC TORTICOLLIS BY DORSAL COLUMN STIMULATION. *(Eng.)* Gildenberg, P. L. (Dept. Surgery, Div. Neurosurgery, Univ. Texas Medical Sch., 6400 W. Cullen St., Houston, TX 77030). *Appl Neurophysiol* 41(1/4): 113-121; 1978. (17 refs)

The results of using an implanted dorsal column stimulator at the C_{1-2} level or transcutaneous stimulation for the treatment of 20 patients with spasmodic torticollis and 2 patients with dystonia musculorum deformans are reported. Initially the response to transcutaneous stimulation was evaluated. This involved the application of two electrodes to the skin of the neck, with the stimulation being controlled by the patient. A standard transcutaneous stimulating unit was employed; the Medtronic NeuroMod Stimulator, the StimTech EPC Personal Stimulator, and the Medgeneral miniCeptor proved satisfactory. Three of the torticollic patients responded satisfactorily enough to transcutaneous stimulation to be treated by this method alone. The remaining patients were evaluated with percutaneous electrodes with a wide range of stimulation frequencies. A consistent pattern was found in which patients reported the typical projection of sensation to the body at frequencies less than 800 Hz. As the stimulation was gradually increased from 800 to 1,100 Hz at a constant voltage, the sensation gradually diminished despite an increase in the total stimulus intensity. At frequencies above 1,100 Hz there was usually no sensation at the same voltage that caused a sensation at lower frequencies. Optimal benefit was found at frequencies of 1,100-1,400 Hz even though the patient had no sensation at that stimulus rate. Six patients with spasmodic torticollis and one patient with dystonia musculorum deformans who were evaluated with transcutaneous and percutaneous dorsal column stimulation had permanently surgically implanted dorsal column stimulators employed for the treatment of their disease. Of these, one patient achieved an excellent response, three a good response, one a fair response, and one

a poor response based on improvement of head positioning, comfort, and decrease in disability. The patient with dystonia musculorum deformans had considerable improvement with dorsal column stimulation but remained disabled. Most patients found it necessary to apply the stimulus for 5-15 min before obtaining relief, but the relief frequently outlasted the stimulus for many hours.

6084 RADIOLOGICAL HEALTH ATTITUDES OF COLLEGE STUDENTS. *(Eng.)* Weinstein, R. D. (Program of Radiologic Technology Education, Sch. Allied Health Sciences, Univ. Texas Health Science Center, Houston, TX 77025). *Radiol Technol* 50(3): 259-263; 1978. (3 refs)

Radiologic health attitudes were surveyed among 622 undergraduate college students using the Radiological Health Attitude Inventory. The study sample comprised 90% freshmen, 7% sophomores, and 3% juniors and seniors attending Texas A&M University in the spring of 1976. The leakage of hazardous levels of radiation from color television sets was considered a problem by 41% of the sample, although 54% disagreed that radar installations are sources of harmful radiation. With respect to attitudes on consumer products, 32% of the sample felt that microwave ovens leak harmful levels of radiation, while 49% disagreed and 18% were undecided. The results of this study indicated that misconceptions toward radiologic health hazards existed in the study sample.

6085 ELECTRICAL STIMULATION FOR VOIDING DYSFUNCTION AFTER SPINAL CORD INJURY. *(Eng.)* Godec, C. (Urology Services, Hennepin County Medical Center, St. Paul, MN); Cass, A. S. *J Urol* 121(1): 73-75; 1979. (25 refs)

The use of electrical stimulation of the anal sphincter in the management of incontinence and/or frequency of voiding in spinal cord injury patients is reported. Urinary incontinence was present in 15 of 18 patients studied, and frequency of voiding was present in more than half of the patients in whom it could be recorded. The criteria for selection of patients with spinal cord injury for treatment with electrical stimulation of the pelvic floor muscles were hyperreflexic bladder function and/or pelvic floor weakness with some innervation of the pelvic floor muscles and an anal sphincter pressure increase of greater than 15 cm of water with electrical stimulation of 15 V maximum. Treatment was either chronic or acute maximal functional electrical stimulation. Chronic stimulation was applied via an anal plug using a continuous train of stimuli. The parameters of stimulation were a pulse duration of 1 msec, a frequency of 20 Hz, and an amplitude of 3-8.5 V (10-15 mA). The patients were instructed to use the stimulator continuously except for voiding and a pause every 2 hr to pass flatus. Acute maximal stimulation was applied via an anal plug and stimulating needle electrodes inserted into the levator ani muscle to increase the input of electrical stimulation. The amplitude of stimulation was 47-50 V (100-150 mA). The duration of each acute maximal application was 15-20 min, and the applications were repeated 4-10 times with 2-3 days between applications. Of 11 patients who were treated with functional electrical stimulation, 9 showed either relief or improvement in their symptoms. Four patients experienced relief after periods of up to 20 mo after stimulation, and another four improved after follow-up periods of up to 10 mo. One patient is still on the device and is improving. An increase in anal sphincter pressure with functional electrical stimulation proved to be a more reliable criterion than an increase in maximum urethral pressure in the selection of patients for the procedure.

6086 COAGULATIVE PROPERTIES OF BLOOD AND TISSUES OF THE CARDIOVASCULAR SYSTEM IN EXPOSURE TO ELECTROMAGNETIC FIELD. *(Eng.)* Kuksinskiy, V. Y. (Dept. Normal Physiology, Chitinskiy Medical Inst., Chita, USSR). 7 pp.; 1978. Translated from Russian--*Kardiologiya* (3): 107-110; 1978. [available through National Technical Information Service, Springfield, VA 22161, Document No. HC A04/MF A01]. (29 refs)

The effects of an electromagnetic field on the coagulative properties of blood and tissues of the cardiovascular system were examined by exposing 50 albino rats for 20 min/day to a low frequency (1,000 Hz) electromagnetic field of 30 V/cm intensity for periods of either 8 or 20 days. After the 8-day exposure, the coagulation activity of the cardiovascular tissues was drastically reduced. This was expressed in a lengthening of the recalcification time, a drop in the tolerance of plasma for heparin, and a decrease in the consumption of prothrombin under the influence of tissue extracts. A rise in the thromboplastic and fibrinolytic activity of the blood was also observed after an 8-day exposure. After the 20-day exposure, an even greater inactivation of both tissue and plasma factors in coagulation and fibrinolysis was noted.

6087 POSSIBILITY OF ATTENUATING THE ECOLOGICAL EFFECTS OF ALTERNATING CURRENT POWER LINES AS A RESULT OF NEW DESIGNS AND CIRCUIT CHANGES. *(Eng.)* Postolatiy, V. M.; Putyatin, S. P. (No affiliation given). pp. 13-22; 1978. Translated from Russian--*Izv Akad Nauk Mold SSR, Ser Fiz Tekh Mat Nauk* (1): 73-79; 1978. [available through National Technical Information Service, Springfield, VA 22161, Document No. HC A04/MF A01]. (7 refs)

The possibility of reducing the ecologic effects of single- and double-circuit alternating current electric power lines (EPL) by means of approximating phases is theoretically examined in reference to the proposed use of ultrahigh voltage EPL (1,150 V or more) in the USSR. With respect to multicircuit EPL, reduction of interphase and intercircuit distances is discussed along with a change in the phase shift of triple-phase voltage systems applied to the circuits. It is shown that the intensity of the electric field generated by an alternating

current EPL near the ground surface can be reduced without altering the clearance distance by 10-15% for single-circuit, triple-phase EPL by approximating the phases to the minimum permissible distance with due consideration of interphase overvoltages; the intensity of the electric field near the ground surface can be reduced by 16-46% when the EPL are constructed in the form of controllable self-compensating lines.

6088 ELECTRIC AND MAGNETIC FIELD CALCULATIONS IN SUPPORT OF BIRD MIGRATION STUDIES AT THE WISCONSIN TEST FACILITY. *(Eng.)* Lanera, D. (IIT Res. Inst., 10 West 35th St., Chicago, IL 60616). 19 pp.; 1978. [available through National Technical Information Service, Springfield, VA 22161, Document No. AD-A057 412]. (4 refs)

Calculations of extremely low frequency (ELF) electric and magnetic fields along specific line paths of birds at the Navy's Wisconsin Test Facility (WTF) are presented in support of studies on the possible effect of ELF fields on bird migration. The WTF consists of two antenna elements installed in a cross-shaped pattern. Each antenna element is approximately 14 miles long and is composed of a cable suspended from poles at an average height of 30 feet above the ground. The antenna elements terminate in grounding electrodes that consist of bare, horizontal, buried wires. The antenna current may be as high as 300 A and is modulated in the frequency band of 72-80 Hz. The two antenna elements can be operated independently or together in any phase relationship: Calculations are presented for the case of a north-south antenna operating alone at a current of 300 A and a frequency of 76 Hz. The results of the calculations are as expected and show field magnitudes that are highest over the antenna and then decrease as the distance increases. A few kilometers away and beyond, no difference is observable among the fields at various altitudes.

6089 HIGH-VOLTAGE POWER LINES AND HUMAN HEALTH. *(Eng.)* Sulpor, B. (Electric Power Res. Inst., 3412 Hillview Ave., P.O. Box 10412, Palo Alto, CA 94303). *Public Util Fortn* 103(1): 11-15; 1979. (0 refs)

Studies on the biologic effects of high-voltage power lines are reviewed. Although Soviet studies have reported such effects as listlessness, excitability, headache, loss of sex drive, drowsiness, and fatigue among electrical switchyard workers, other studies on substation and transmission line workers in Canada, England, France, West Germany, Italy, and the United States have failed to demonstrate these effects. Animal studies at the Veterans Administration Hospital in Syracuse, New York have shown that rats exposed for 30 days to an electric field experienced a response similar to that undergone by an animal or human suffering from stress. It was also found that mice exposed to a vertical electric field for three successive generations were stunted. However, tests under way at Battelle on mice, rats, and swine as well as tests completed recently at the University of Utah on rats have failed to confirm the above results. The only biologically significant and confirmed observation of nearly 500 tests made thus far at Battelle is that rats, when given a choice, spend more time out of the electric field than in it when field strengths are greater than 15 kV/m. Other studies have demonstrated that some plants are slightly damaged by electric fields. Field tests involving the placement of shielded and unshielded beehives between two 765-kV transmission towers demonstrated that less honey was produced in unshielded metal hives and that bees from these hives weighed less than controls. It was also noticed that honeybees on the outside of nonmetal unshielded hives stung one another. This aggression was attributed to an electric current buildup on these particular hives, which contained polyethylene and were nonconductive. The investigators in these experiments state that it is still too early to determine the significance of these results.

6090 PRELIMINARY CLINICAL TRIALS OF ELECTROPHORETIC IONIZATION IN THE TREATMENT OF MALIGNANT TUMORS. *(Eng.)* Nordenstrom, B. (Dept. Diagnostic Radiology, Karolinska sjukhuset, S-104 01 Stockholm 60, Sweden). *IRCS Med Sci: Cancer* 6(12): 537; 1978. (2 refs)

Local electrophoretic ionization was used to treat seven inoperable lung metastases in five patients (ages, 20-68 yr). Teflon insulated platinum electrodes (0.2 mm thick) with the distal 20 mm free from insulation were implanted percutaneously under local anesthesia. One electrode was placed in the tumor and one in the surrounding tissue or in a vessel supplying the tumor. A 10- to 15-V direct current was then applied, with the tumor being electropositive. An initial current of 5-10 mA was then increased gradually to 30-40 mA, producing intensive tissue ionization. The electropositive tumor tissue turned into a dry gangrene surrounded by diapedetic bleeding, thrombosis, and intensive leukocyte attraction. The tissue around the electronegative electrode became edematous by field-induced electro-osmosis with some minor tissue destruction and mainly vascular contractions. No serious complications resulted from treatment, and temporary production of pneumothorax was easily managed. Six of the tumors showed a gradual decrease in size at various times after treatment. Although this form of treatment seems promising, the long-term effects cannot yet be evaluated.

6091 THE EFFECT OF HYPERTHERMIA ON SURVIVAL IN TRANSPLANTED LYMPHOSARCOMA. *(Eng.)* Malangoni, M. A. (Section Pediatric Surgery, Dept. Surgery, Indiana Univ. Sch. Medicine, Indianapolis, IN); Grosfeld, J. L.; Cakmak, O.; Ballantine, T. V. *J Pediatr Surg* 13(6D): 740-745; 1978. (28 refs)

The effect of 2,450-MHz microwave-induced hyper-

thermia on the survival of C3H mice bearing transplanted Gardner lymphosarcoma was investigated. On day 7 after 73 mice received subcutaneous injections of 1.2 x 10^6 tumor cells, the animals were randomly assigned to one of four treatment groups. Group I animals served as controls and received no treatment. Group II mice were given a single intraperitoneal injection of cyclophosphamide (CP) at a dose of 50 mg/kg. Group III mice received a single dose of microwave irradiation. Group IV mice were treated with both CP and microwaves at the same doses that were administered to Groups II and III. Microwave treatment was given for 4 min at a power of 40 W. The tumor temperature averaged 41.5 C in both Group III and IV animals. Control animals (Group I) and mice receiving microwave therapy alone (Group III) did not survive the 21-day experimental period. Group II mice treated with CP only had a survival rate of 45% (9/20 animals). The survival rate of mice treated with both CP and microwaves was 79% (15/19 animals); this was significantly better than the survival rate of Group II mice treated with CP only. Histologic evaluation at 21 days showed areas of central tumor necrosis surrounded by normal tumor. There was evidence of vascular degeneration and thrombosis in the more central tumor regions. Tumor size was decreased similarly in both Groups II and IV mice. These data demonstrate a synergistic effect of CP and microwave-induced hyperthermia in this highly lethal transplanted lymphosarcoma. It is concluded that the concomitant use of hyperthermia and chemotherapy may be of value in the treatment of certain neoplastic diseases.

6092 NONTHERMAL BIOEFFECTS SUGGESTED AT 2450 MHZ. *(Eng.)* Anonymous. (No affiliation given). *Microwaves* 17(12): 16, 19, 28; 1978. (0 refs)

The effects of 2,450-MHz microwave radiation on the behavior and blood chemistry of rats were studied at the University of Washington in Seattle to replicate research conducted at the Kiev Institute of Industrial Hygiene in the Soviet Union. Eight rats (with eight control animals) were exposed to continuous wave radiation for 7 hr/day. The average absorbed energy was 0.5 W/kg, which was measured by monitoring input and reflected and transmitted power with a twin-well calorimeter. After 3 mo of irradiation, behavior effects involving sensory, physical, and learning responses were observed. Adverse effects were also observed in rat blood content. After 1 mo of exposure, irradiated rats showed a 10-15% decrease in some blood enzymes. However, during mo 2 and 3, enzyme levels were normal. Perhaps the most quantitative change noticed was an imbalance of sodium and potassium in the rats' blood. During the 3 mo of irradiation, sodium levels increased and potassium levels dropped. Sodium and potassium concentrations are controlled by the adrenal glands, and microscopic observation of adrenal cells showed that they were swollen, which is a symptom of excessive sodium production and sloughing of potassium. At the power level used in these experiments (0.5 mW/cm^2), temperature changes were too small to measure as the animal's cooling system dissipates heat before a change can be measured. The researchers in this study are not yet totally willing to say that the above effects are nonthermal, however.

6093 EXACT ANALYSIS FOR CALCULATING HEMODYNAMIC PARAMETERS IN UNSTEADY BLOOD FLOW IN ARTERIES IN PRESENCE OF STATIC MAGNETIC FIELD. *(Eng.)* Kumar, V. (Old E-9 Residences, Regional Engineering Coll., Kurushetra, Haryana, Pin 132119, India). *Stud Biophys* 72(1): 43-50; 1978. (7 refs)

An exact analytic solution in the closed form for calculating hemodynamic parameters in unsteady laminar blood flow through a straight, rigid, circular artery under the influence of a static transverse magnetic field of arbitrary strength is presented. The blood was assumed to be a conducting and incompressible Newtonian liquid. Using the method of separation of variables, the governing equation in dimensionless form was split into two ordinary differential equations, one being of first order and the other being a second order nonhomogeneous differential equation. The first-order differential equation was solved directly, while the second was solved using the infinite fourier series. The other hemodynamic parameters were also derived analytically (from the axial velocity distribution) in the closed form without using any approximation. Numeric data were calculated for a human femoral artery. It is concluded that the quantity of blood flowing and also the shear stress are reduced with increasing magnetic fields in the transverse direction for a given oscillation. It is also concluded that with higher pulsation the total quantity of flow as well as the shear stress are decreased for a given transverse magnetic field.

6094 DIELECTRIC RELAXATION OF COLLAGEN IN AQUEOUS SOLUTIONS. *(Eng.)* Umemura, S. (Applied Physics, Faculty Engineering, Univ. Tokyo, Bunkyo-ku, Tokyo 113, Japan); Sakamoto, M.; Hayakawa, R.; Wada, Y. *Biopolymers* 18(1): 25-34; 1979. (20 refs)

The dielectric relaxation of collagen in aqueous solutions was studied. The complex dielectric constant of collagen in aqueous solutions at a polymer concentration (Cp) of 0.02-0.2% was measured at a temperature of 10 C in the frequency range of 3 Hz-30 kHz. The dielectric loss peak for a Cp of 0.02% was located at 90 Hz, and the dielectric relaxation time (DRT) was estimated to be 1.8 ± 0.3 msec. This DRT agreed well with the rotational relaxation time estimated from the reduced viscosity, and the relaxation was ascribed to the end-over-end rotation of the molecule. The Cp dependence of DRT and the dielectric increment (DI) were interpreted in terms of the aggregation of molecules. The dipole moment of a molecule, obtained from DI at a Cp of 0.02% and a pH of 6.5 was calculated to be equal to 5.2 ± 0.2 x 10^4 times the rotational dif-

fusion constant. This was explained by the asymmetrical distribution of the ionized side chains of the molecule.

6095 CEREBELLAR STIMULATION FOR EPILEPSY AND CEREBRAL PALSY. *(Eng.)* Anonymous. (No affiliation given). *Lancet* 2(8103): 1290; 1978. (2 refs)

The use of chronic cerebellar stimulation (CCS) for the treatment of epilepsy and cerebral palsy is discussed. The usual procedure is to place silicon-mesh plates, bearing platinum electrodes, bilaterally on the anterior and posterior lobes of the cerebellum. The operation is done under general anesthesia via 3-cm (diameter) craniectomies; subcutaneous leads pass to a subcutaneously implanted receiver that is activated by a radio frequency signal from a power pack carried by the patient. The best position and number of electrodes and the best type of pulse have still to be determined. Also, the current required to elicit neurophysiologic evidence of inhibition varies between patients, and too much current may worsen symptoms. Data on 32 patients (ages, 14-56 yr) with epilepsy (length of illness, 3-49 yr) who were followed up for 13-53 mo after treatment with CCS indicate that 18 patients had a good clinical response (at least 50% reduction of seizures). Nine patients were therapeutic failures, but none was made neurologically worse by the procedure. Experience with CCS in 141 patients with cerebral palsy (ages, 7-55 yr) indicated moderate to marked overall improvement in 46% and mild improvement in 39%. Cerebellar biopsy specimens were taken at operation from 30 of the 173 patients comprising both of the above groups, and 3 patients were autopsied. As in animals, the stimulating electrode produced a limited lesion without fibrosis; however, there was no evidence of serious harm from CCS. It is concluded that electrical stimulation of the cerebellum or spinal cord is the only really promising approach in patients with cerebral palsy. In cases of epilepsy, it is possible that cerebellar stimulation will now save some patients from ablative surgery.

6096 AUTO-ELECTROTHERAPY IN NERVE LESIONS. *(Eng.)* Cugola, L. (Orthopedic Clinic, Univ. Verona, Verona, Italy); Tarolli, G. *Rand* 10(3): 279-282; 1978. (0 refs)

A portable auto-electrotherapy generator designed for the treatment of upper limb nerve injuries is described. The device is battery operated and automatically generates impulses at 3-60 sec intervals. The intensity of the electrical impulses can be varied from 1-10 mA, and the impulse duration is about 30 msec. The device can be used with either a brush stimulator, which the patient applies to pre-established points, for providing selective therapy to muscles requiring intensive treatment or with a glove embedded with electrodes for the simultaneous stimulation of many muscles or muscle groups. Three possible patterns of stimulation can be achieved. The first involves stimulation of the intrinsic muscles (using two plates, one in the palm for the lumbricals and the other on the back of the hand for the interossei and thumb adductor) plus stimulation of the thenar and hypothenar muscles by plates on the respective eminences. The second stimulation pattern involves stimulation of the extensors using three plates. One is placed on the proximal third of the forearm for the radial extensors of the wrist and the common digital extensors. A second is placed on the middle third for the ulnar extensors, and a third is placed over the distal third for the thumb abductors and extensors. The third stimulation pattern involves stimulation of the wrist and hand flexors. Three plates are used; one for the brachioradialis, a second for the radial wrist flexors, pronator teres, and flexor carpi ulnaris (both placed in the proximal third of the front of the forearm), and a third plate in the distal third for the flexor pollicis longus and digital flexors. The device can be used either for nerve injuries using a reduced number of plates or for multiple injuries when the maximum number of plates is used.

6097 ARE MICROWAVES HARMLESS? *(Ger.)* Anonymous. (No affiliation given). *Solvefa Rundfftung* 96(50): 982-983; 1978. (0 refs)

Studies concerning the thermal and non-thermal biologic effects of microwaves on microorganisms conducted at the Max-Planck Institute of Solids Research are reported. The microwave energy absorbed by microorganisms and their components is being measured using highly sophisticated methods. The effects of microwave radiation on 10 consecutive generations of yeast cell cultures are being studied. There is as yet no scientific evidence of the non-thermal effect of microwaves.

6098 THE RADIATION SAFETY OF MICROWAVE OVENS. *(Dut.)* Anonymous. (No affiliation given). *Ned Tijdschr Geneeskd* 122(50): 1978; 1978. (0 refs)

The radiation leakage from microwave ovens is generally not hazardous. The maximum permissible leakage radiation intensity, measured at 5 cm distance, is set at 5 mW/cm^2 in the Netherlands, but new ovens with a radiation intensity exceeding 1 mW/cm^2 cannot be sold because the radiation intensity is believed to increase during the use of the oven.

6099 PROTECTION OF SUBSCRIBERS AND WIRED RADIO-RELAY INSTALLATIONS FROM DANGEROUS VOLTAGES AND CURRENTS OCCURRING ON RADIO-RELAY NETWORK LINES. *(Eng.)* USSR Central Scientific Res. Inst. Communications. (No affiliation given). 18 pp.; 1977. [available through National Technical Information Service, Springfield, VA 22161, Document No. AD-A052550]. (0 refs)

Standards for the protection of subscribers and wired radio-relay installations from dangerous vol-

tages and currents occurring on radio-relay network (RRN) lines in the USSR are presented. These standards were promulgated by decree of the Committee on Standards, Measures, and Measuring Instruments of the Council of Ministers USSR on July 25, 1969. The period of the introduction of these standards is established from January 1, 1970. Specific standards are provided for the following: the protection of radio-relay equipment connected to feeder lines of more than 360 V; the protection of equipment with connected RRN feeder lines of up to 360 V; the protection of subscribers and equipment on 15- and 30-V subscriber lines; the protection of cable inserts and loading coils of RRN overhead lines; the protection of apparatus at receiving antenna inlets; and the protection at intersections of RRN lines with transmission lines or with contact wires of electric-powered ground transportation systems.

6100 HIGH-TENSION ELECTRICAL INJURY. *(Eng.)* Anonymous. (No affiliation given). *Lancet* 2(8097): 978; 1978. (5 refs)

The effects of high-tension electrical shock (usually 11,000 V or more) are discussed. Tissue damage is largely due to the conversion of electrical energy to thermal energy. According to Joule's law, when a current passes through a conductor the power (heat) is proportional to the amperage squared times resistance; thus, bone and skin, which are poor conductors of high resistance, will very efficiently convert electrical energy to thermal energy. This accounts for the severe damage to periosseous muscles beneath viable tissue. When the current in a high-tension accident arcs, commonly from the palm to the volar aspect of the wrist, there is a voltage drop absorbing much of the electrical energy as the air particles become ionized. The temperature in such an arc can reach 4000 C, with burning of tissue and ignition of clothing. Thus, tissue damage can result from both the heat of the electric arc and the flow of current. Particular attention must be paid to the tissue damage at the site of contact. Immediate decompression by escharotomy and fasciotomy must be followed by debridement of dead tissue. Any progressive necrosis of muscle results from infection and hypoxia and is prevented by thorough debridement of all dead muscle, especially around bone. Nerves and tendons, even if apparently not viable, should be spared since some regeneration is possible if good cover is provided early with a skin flap.

6101 STUDIES ON THE INTERACTION OF MICROWAVE RADIATION WITH CHOLINESTERASE. *(Eng.)* Olcerst, R. B. (Inst. Environmental Medicine, New York Univ. Medical Center, 550 First Ave., New York, NY 10016). Rabinowitz, J. R. *Radiat Environ Biophys* 15(3): 289-295; 1978. (15 refs)

The effect of 2.45-GHz microwave irradiation on the enzymatic activity of the stereospecific protein acetylcholinesterase in aqueous solution and in defibrinated rabbit blood was studied. At power densities of up to 100 mW/cm^2 for uncooled exposures of 30 min and for a large number of 3-hr cooled exposures at 25 mW/cm^2, there was no significant difference between irradiated samples of the purified enzyme in aqueous solution and control samples. A 30-min uncooled exposure at a power density of 125 mW/cm^2 caused a significant drop in the initial velocity of the enzyme. However, in this experiment, the temperature was allowed to rise during irradiation and was 60 C after 30 min. At this temperature, thermal denaturation would cause irreversible changes in the enzyme structure. Microwave radiation of defibrinated rabbit blood had no effect on the total cholinesterase activity at levels of 21, 35, and 64 mW/cm^2 for both continuous wave and square wave modulated irradiation (pulse width, 0.75 msec and 0.71 pulses/msec). In this series of experiments, the heat exchange system maintained a temperature of 37 ± 0.5 C in both controls and irradiated samples. Since changes in enzyme activity could be affected in the in vivo calcium and magnesium in the serum, a similar irradiation procedure was used to investigate the release of bound calcium and magnesium from rabbit red blood cells. No change in the levels of magnesium and calcium in cell-free serum was found after 3 hr of irradiation of defibrinated rabbit blood in a temperature controlled system. Overall, these studies showed no direct effect of microwave radiation on acetylcholinesterase activity.

6102 EFFECTS OF RADIO-FREQUENCY RADIATION ON INFLAMMATION. *(Eng.)* Liburdy, R. P. (Radiation Sciences Div., USAF Sch. Aerospace Medicine, Brooks Air Force Base, TX 78235). *Radio Sci* 12(2): 179-183; 1977. (19 refs)

The effect of pretreatment with continuous wave 26-MHz radio frequency (RF) radiation was compared with that of warm air heating (79 C) on inflammatory responses that were induced in rats by a subcutaneous injection of sheep red blood cells (SRBC) into footpads and in mice by tail vein trauma due to sequential bleeding. Both RF radiation (4-7 min) and warm air (8-12 min) exposures were matched to induce an increase of body temperature between 2 and 4 C. At 4 hr after the injection of SRBC into footpads of rats, animals that were pretreated with RF radiation showed an averaged thickness of footpad that was 33.0% and 45.6% less, respectively, than those of warm air-treated and sham-exposed animals. Thus, RF radiation pretreatment protected significantly against the development of SRBC-induced inflammation. The white blood cell counts in RF pretreated tail vein traumatized mice remained constant in contrast to a leukocytosis (7,000 cells/cm^3 increasing to 15,000 cells/cm^3 at 12 hr) for warm air and sham-treated mice. Moreover, the inflammatory response in RF-pretreated mice was accompanied by a well defined, transient refractory state in the circulating white blood cell population that was characterized by a fourfold decrease of lymphocytes and a concomitant fourfold increase in neutrophils. The refractory lymphopenia contrasts with the monotonic panleukocytosis that was observed in warm air- and sham-exposed mice. The fact that RF pre-

treatment of mice resulted in a fourfold increase of neutrophils at 3-6 hr after exposure serves to explain the twofold difference in footpad swelling that was observed at 4 hr postexposure between RF- and sham-exposed rats that were inoculated with SRBC. The results indicate that RF radiation can attenuate an inflammatory reaction. This inhibitory property may have relevance to immunocompetency of cell-mediated immunity (CMI) since CMI responses invoke nonspecific inflammatory reactions.

6103 TESTS FOR HUMAN PERCEPTION OF 60 Hz MODERATE STRENGTH MAGNETIC FIELDS. *(Eng.)*
Tucker, R. D. (Biophysics Group, 200 T.N.C.E., Electrical Engineering, Univ. Minnesota, Minneapolis, MN 55455); Schmitt, O. H. *IEEE Trans Biomed Eng* BME-25(6): 509-518; 1978. (13 refs)

Human subjects were exposed to 60-Hz magnetic fields varying in field strength from 7.5-15 G (root mean square) to determine if they could detect or learn to detect by biofeedback training the presence of a moderate magnetic field. Preliminary experiments revealed that some very perceptive individuals unintentionally used subtle auxiliary clues to develop impressive records of apparent magnetic field detection. A tightly sealed subject chamber was developed to provide extreme isolation against these clues, and a large number of individuals were tested in this system with computer randomized sequences of 150 trials per individual. An analysis of the whole experimental series showed that each successive improvement in isolation from field associated clues resulted in lowered perception, until not even biofeedback learning could produce significant perception. Neither gradient fields nor higher strength fields concentrated about the subject's head showed significant perception. The results appear to establish that these fields are not normally sensed. Magnetic headaches that were experienced by subjects in placebo experiments where the fields were never turned on suggest that many of these reported discomforts may be iatrogenic, technogenic, or produced by simple fear of the unknown.

6104 INTRACELLULAR HYPERTHERMIA: SELECTIVE CANCER CELL DESTRUCTION BY THE BIOPHYSICAL ALTERATION OF INTRACELLULAR PROPERTIES. *(Eng.)*
Gordon, R. T. (4936 W. Estes, Skokie, IL 60077); Hines, J. R.; Gordon, D. *IRCS Med Sci: Cancer* 6 (10): 425-426; 1978. (10 refs)

The use of electromagnetic field-induced intracellular hyperthermia for the selective destruction of cancer cells is described. Using induced heat energy after tumor phagocytosis of magnetically excitable submicron particles, the cancer cell membrane (composed of lipids and proteins), which is an excellent thermal barrier and a very poor thermal conductor, is utilized to contain the energy within the cancer cell, resulting in the selective thermal destruction of cancer cells. Any magnetic or electric dipole contained, introduced, or capable of being produced by an external field can be used. This new approach uses a frequency sufficiently low (450 kHz) so that there is virtually no tissue heating and no damage to normal cells; the heating is generated intracellularly, i.e., within the cell, itself. Sprague Dawley rats with spontaneous mammary tumors (adenocarcinomas and fibroadenomas) were injected in the tail vein on 3 successive days with 2 cm^3 of a solution that contained iron-containing particles. The entire animal was exposed to a 450-kHz electromagnetic field (30 kW) for 12 min, beginning 48 hr after the last injection. Electron microscopy and light microscopy confirmed the destruction of cancer cells. In animals where the tumor cells were destroyed, all normal tissues were histologically unchanged including those containing particles. In animals where the tail injections were subcutaneous instead of intravenous such that the animal did not receive any particles intravenously, the same exposure to the electromagnetic field had no effect on the tumor cells or on the normal cells and tissues. The selectivity of the particles for the cancer cells in this method may be enhanced using particles bound with antibodies or radioisotopes, and localized magnetic fields may be applied to concentrate more particles in the tumor. It is concluded that the described method represents a new effective treatment of cancer by intracellular alteration of biophysical properties resulting in the selective destruction of cancer cells without affecting normal cells and tissues.

6105 A COMPARATIVE STUDY OF THE EFFECTS OF MICROWAVE RADIATION AND CONVENTIONAL HEATING ON THE REPRODUCTIVE CAPACITY OF *DROSOPHILA MELANOGASTER*. *(Eng.)* Pay, T. L. (U.S. Dept. Health, Education, and Welfare, Public Health Service, Food and Drug Admin., Bureau Radiological Health, 5600 Fishers Lane, Rockville, MD 20857); Andersen, F. A.; Jessup, G. L., Jr. *Radiat Res.* 76(2): 271-282; 1978. (10 refs)

The effects of continuous wave 2,450-MHz microwave radiation (dose level, 0.644 W/g for 10 min) and conventional water-bath heating (44 C) on the egg-laying pattern of female fruit flies *(Drosophila melanogaster)* and on the viability of eggs produced were investigated. The temperature of 44 C was chosen to obtain the same percentage kill as in the microwave-exposed group. The egg production of females exposed to heat and females exposed to microwave radiation was significantly reduced when compared with their respective sham groups. However, there were no significant differences in egg production between females exposed to microwave irradiation and those exposed to conventional heating. There was a significant difference in the survival of eggs laid by both the heat-exposed and the microwave-irradiated females when compared to their respective sham groups. In the heat-exposed group, the survival was significantly greater than that of their shams, whereas in the microwave-irradiated group, a significant decrease in survival was seen in comparison with the respective sham group. The difference in the survival of eggs laid by heat-exposed and microwave-irradiated females was statistically significant ($p<0.01$). Both the mean number of eggs produced and the mean percentage survival of eggs laid by normal

females mated to treated males was not significantly different from their respective sham groups regardless of whether the males were exposed to heat or irradiated with microwaves. It is concluded that the two treatments used do not produce results consistent with identical mechanisms of action, although heating may be involved in each case. It remains to be seen if the reduced survival of eggs produced by microwave-irradiated females is due to a damage mechanism that is completely separate from that which caused the increased survival of eggs produced by females exposed to conventional heating.

6106 TEMPERATURE UNIFORMITY IN HYPERTHERMAL TUMOR THERAPY. *(Eng.)* Harrison, G. H.; Robinson, J. E.; Samaras, G. M. *In: Hyperthermia as an Antineoplastic Treatment Modality. Proceedings of a Symposium Sponsored by Langley Res. Center, Hampton, VA, and Eastern Virginia Medical Sch., Norfolk, VA, January 28, 1978.* NASA Conference Publication No. 2051. pp. 27-32; 1978. (6 refs)

The temperature uniformity of mouse mammary tumors transplanted in the flank or hind leg of C3H mice was measured during water bath- or microwave-induced hyperthermia. Tumors implanted on the mouse flank were easily heated to uniformities within 0.1 C by using water baths. However, when the same tumors were implanted on the hind leg, cold spots were observed during water bath heating. Two thermal profiles taken through a leg tumor are illustrated. The tumor was roughly ellipsoidal in shape and measured 15 by 12 by 8.5 mm along the three orthogonal major axes. The water bath in which it was immersed was maintained at 42.9 C. One profile was taken along a line near the leg bone, but well within the tumor. The second was taken about one-third of the way into the tumor on the side away from the bone. The profile showed marked temperature variations, with temperatures measured being as low as 41.6 and 42.2 C for the thermal scans near and away from the bone. To overcome this cold spot problem, heating was performed with combined 2,450-MHz microwaves and a temperature-controlled liquid bolus (80% by weight of isotonic and saline and 20% by weight of ethanol). The tumor was surrounded with the liquid bolus in plane-parallel-slab geometry and was irradiated with parallel-opposed microwave beams. The liquid bolus was maintained at 42.9 C, and the tumor with bolus was irradiated with a microwave power of 22 W. Heating with combined microwaves and temperature-controlled liquid bolus significantly improved the thermal uniformity within the tumor. The cold spots observed during water bath hyperthermia were attributed to cooling of the tumor by major blood vessels near the tumor. The above observations might have some bearing on the discrepancies in biologic hyperthermia data for different tumors subjected to apparently similar thermal treatments. It is suggested that careful thermal studies are even more important to thermobiology than good radiation dosimetry is to conventional radiobiology.

6107 THE COMBINED EFFECTS OF PULSED RADIATION (DIAPULSE) AND CHEMOTHERAPY ON TUMOR BEARING MICE. THE MEASUREMENT OF RODENT PALATAL EXPLANTS AS A DEVICE FOR MEASUREMENT OF THE BIOLOGIC EFFECTS OF NONIONIC RADIATION (EMR). *(Eng.)* Regelson, W.; West, B.; DePaola, D. P. *In: Hyperthermia as an Antineoplastic Treatment Modality. Proceedings of a Symposium Sponsored by Langley Res. Center, Hampton, VA, and Eastern Virginia Medical Sch., Norfolk, VA, January 28, 1978.* NASA Conference Publication No. 2051. pp. 54-66; 1978. (17 refs)

The combined effects of pulsed radiowave (diapulse) irradiation and chemotherapy on the lifespan of BDF_1 mice injected subcutaneously with 10^6 Lewis lung carcinoma cells in the flank were investigated. The diapulse generator operated at a carrier frequency of 27.12 MHz, which was pulse modulated over a frequency range of 80-600 cps. At maximum settings, the treatment unit supplied 974 W of instantaneous power with a 3.9%-duty cycle; the pulse duration of 65 μsec. This yielded a highest average power output of 38 W. Experiments were also performed at a low mean power of 4 W. Mice receiving cancer chemotherapy alone in the form of hydroxyurea (HU) had an increased lifespan (ILS) of 22.1% over untreated controls. Mice receiving HU plus low-power irradiation (mean, 4 W) had an ILS of 5.1% over controls. Mice receiving HU plus high-power irradiation (mean, 38 W) had an ILS of 101.9% over controls. Mice receiving chemotherapy alone in the form of Cytoxan (CTX) had an ILS of 64.1% over controls. Mice receiving CTX plus high-power irradiation had a 74.1% ILS, and those receiving CTX plus low-power irradiation had a 106.6% ILS in comparison with controls. Mice receiving a combination of HU and CTX showed a 41.2% decrease in lifespan compared with untreated controls. Mice receiving a combination of HU and CTX plus low-power irradiation had an ILS of 38% over untreated controls, and mice receiving HU and CTX plus high-power irradiation had an ILS of only 1.7% over untreated controls. Overall, simultaneous treatment with pulsed radiowave radiation and chemotherapy significantly extended the lifespan of tumor-bearing mice. For example, in comparison with non-treated controls, the combination of HU and whole body radiation produced a differential enhancement of longevity depending on the power output. The combination of HU and high-power irradiation produced a mean extension of life that was 67% greater than that for mice treated with HU alone. Since the stress involved in confining mice to holders and subjecting them to nonionic radiation and chemotherapy produced significant variability in tumor growth, an in vitro system of quantifying the biologic effects of radiation was investigated. Palatal explants from 14-day-old mouse embryos suspended in tissue culture were studied as the radiation target. However, technical problems related to timing of mouse pregnancy and palatal harvest suggested that this method of biologic assay currently has variables equal to those of tumor growth studies in the living mouse.

6108 FOCUSSED MICROWAVE RADIATION THERAPY FOR DEEP TUMORS. *(Eng.)* Samaras, G. M.; Robinson, J. E.; Cheung, A. Y.; Weinmann, S. F. *In: Hyperthermia as an Antineoplastic Treatment Modality. Proceedings of a Symposium by Langley*

Res. Center, Hampton, VA, and Eastern Virginia Medical Sch., Norfolk, VA, January 28, 1978. NASA Conference Publication No. 2051. pp. 67-70; 1978. (8 refs)

Systems designed to focus microwave radiation for the heating of deep tumors are described that are based on the concept of superposition of separate radiation beams. The application of this multiple-beam paradigm to microwave diathermy offers the potential of generation and control of spatio-temporally complex thermal fields deep within the body. A prototype system consisting of two parallel-opposed simulated TEM applicators operating at 2,450 MHz with power time-multiplexed either between the treatment beams or off to an air-cooled load has been developed. Using this system it has been found that the central axis tissue temperature profile is parabolic as would be predicted by superposition of energy deposition in tissue. In tumor regrowth studies with C3H murine mammary carcinomas transplanted to the flank of mice, it was found that the delay in tumor regrowth following microwave treatment compares favorably with the results obtained in previous water bath studies. Currently a programmable system (microprocessor controlled) is under evaluation and software development. The system is capable of supporting 16 miniature applicators and controlling the output power of each applicator while monitoring forward and reflected power, temperature, and physiologic parameters. While currently being operated at 915 MHz, the control system is frequency-independent and will be operated at a lower frequency when clinical trials commence. The programmable system is currently being used to study the efficacy of focussed heating in a feline brain through the measurement of electric and resultant thermal fields. The major limitation of microwave diathermy in cancer thermotherapy is the equipment's ability to heat deep tumors and at the same time spare the intervening tissue. With the development of technology for focussing the heat to the tumor site, the utility of local microwave-induced hyperthermia as an adjunct to radiotherapy and chemotherapy in the clinical management of some cancers should be improved, especially in cases involving malignant brain tumors.

6109 GENERAL STATEMENT ON HYPERFREQUENCIES AND THEIR BIOLOGICAL EFFECTS. *(Fre.)* Servantie, B. M. (Hopital d'Instruction des Armees Sainte-Anne, 83800 Toulon Naval, France); Klein, M. J. *In: Effets Biologiques des Rayonnements Non Ionisants--Utilisation et Risques Associes.* Proceedings of the Ninth International Congress of the Societe Francaise de Radioprotection. (Nainville-les-Roches, France): pp. 215-253; 1978. (102 refs)

Literature on the biologic effects of microwaves published since 1958 is reviewed. An analysis of data in about fifty papers indicates that the terminology "thermal" and "nonthermal" or "specific" fails to accurately describe or differentiate between the effects of microwave activity. Effects appear to be related rather to the power density (mW/cm^2) absorbed by the irradiated biologic unit. Methods of calculating the absorption of electromagnetic energy from a microwave source are discussed. Biologic effects at the cellular level, on the central nervous system, and on the blood-brain barrier of experimental animals, and on humans are reviewed. The thermal effects of microwave radiation on biologic tissue have led to efforts to devise therapeutic applications particularly for cancer. Problems of focusing the radiation on the pathologit tissue are not yet resolved. Finally, the problem of defining safe microwave exposure levels for both the population at large and workers is considered. Dangerous levels have been defined as less than 1 $\mu W/cm^2$, less than 0.1 mW/cm^2, and about 10 mW/cm^2 by various national agencies. It is concluded that an ideal system for defining dangerous exposure levels has not yet been devised. Further research and public awareness are crucial.

6110 EFFECT OF MICROWAVES ON DEVELOPMENT OF GONADS AND ADRENAL GLANDS IN THE NEWBORN RAT. *(Fre.)* Maniey, J. (Laboratoire de Physiologie des Regulations, Universite de Rennes, Rennes, France); Le Ruz, P.; Plurien, G. *In: Effets Biologiques des Rayonnements Non Ionisants--Utilisation et Risques Associes.* Proceedings of the Ninth International Congress of the Societe Francaise de Radioprotection. (Nainville-les-Roches, France): pp. 257-264; 1978. (0 refs)

The effect of exposure of newborn rats for 15 consecutive days to radiation from a radar emitter (pulsed beam of 3 GHz with a horizontal repetition frequency of 500 Hz; power density of 5-10 mW/cm^2) on gonadal and adrenal development was studied. White Sherman rats born and raised in laboratory cages maintained at a temperature of 22 ± 2 C and exposed to 12 hr of artificial light per 24 hr were utilized. Animals were weaned at 21 days and then fed on a standard diet. After sacrifice at age 60, 90, or 140 days, testes or ovaries and adrenal glands were weighed and examined histologically. No effects were observed in rats killed at age 60 days. Irradiated rats killed at 90 days had testes that were reduced in weight as compared to controls (2.65 ± 0.15 g compared to 3.00 ± 0.13 g) as well as smaller ovaries (79.60 ± 4.06 mg compared to 88.45 ± 4.04 mg). Exposed rats killed at 140 days also had smaller testes (2.79 ± 0.15 g compared to 3.05 ± 0.07 g) and ovaries (71.22 ± 6.8 mg compared to 88.38 ± 10.35 mg). Histologic examination of irradiated rats revealed closed seminiferous tubes and blocked spermatogenesis in testes and reduced oocyte formation in ovaries. Adrenal glands were smaller in irradiated female rats killed at 140 days (48.08 ± 3.45 mg compared to 56 ± 5.70 mg), but not in irradiated males. Blood corticosteroids, measured after subjecting rats to stress (3 min of isolation under small glass bell), were increased in rats killed at 90 days (males: 33.23 ± 3.49 µg versus 2.87 ± 2.9 µg; females: 82.34 ± 7.64 µg compared to 60.96 ± 9.58 µg). The position of the cage in relation to the radiation source had a significant effect on the reduction in the weight of the glands.

6111 EFFECT OF MICROWAVE RADIATION (2,450 MHz) ON THE PITUITARY-TESTICULAR AXIS IN THE WHITE RAT. *(Fre.)* Dechaux, P. (Laboratoire de Physiologie Cellulaire, Universite Claude Bernard, 69621 Villeurbanne, France); Pelissier, J. P.; Santini, R.; Fontanges, R. *In: Effets Biologiques des Rayonnements Non Ionisants--Utilisation et Risques Associes.* Proceedings of the Ninth International Congress of the Societe Francaise de Radioprotection. (Nainville-les-Roches, France): pp. 265-269; 1978. (2 refs)

The effect of exposure for 24 hr to microwaves (2,450 MHz; industrial band, 10 mW/cm^2) on pituitary and gonad gland function of Sprague-Dawley rats was investigated. Rats, aged 60 days at time of irradiation, were decapitated 10 min, 3, 8, and 15 days after irradiation. Plasma levels of testosterone and luteinizing hormone (LH) were measured by radioimmunoassay in blood from killed animals. LH increased (83 ± 3.2 ng/ml compared to 70 ± 5.0 ng/ml; $p<0.01$) 10 min after irradiation, was the same as controls 3 days after irradiation (73 ± 2.5 ng/ml) and fell to less than control levels (52 ± 1.2 ng/ml compared to 65 ± 3.0 ng/ml; $p\leq0.1$) after 8 days. Plasma levels of testosterone were significantly increased 3 and 8 days after irradiation (285 ± 30 ng/100 ml compared to 180 ± 10 ng/100 ml; $p\leq0.05$ at 3 days: 630 ± 100 ng/100 ml compared to 350 ± 65; $p\leq0.1$ at 8 days). The pituitary gland was apparently affected by irradiation directly since LH levels rose within 10 min; testosterone levels then rose by feed-back mechanism. Normal hormonal equilibrium was reestablished 15 days after irradiation.

6112 COMPARISON OF THE EFFECT OF MICROWAVES ON THE LIPID METABOLISM OF SEVERAL MOUSE STRAINS. *(Fre.)* Dumas, J. C. (Laboratoire de Physiologie, Faculte de Pharmacie, 31 allees Jules-Guesde, 31400 Toulouse, France); Laurens, S.; Plurien, G. *In: Effets Biologiques des Rayonnements Non Ionisants--Utilisation et Risques Associes.* Proceedings of the Ninth International Congress of the Societe Francaise de Radioprotection. (Nainville-les-Roches, France): pp. 271-276; 1978. (4 refs)

A comparison was made of the levels of triglycerides (TRG) in three types of mice, C57B1, DBA, and Swiss, exposed to microwaves at a frequency of 2,450 MHz for 59 hr consecutively. Mice were irradiated in anechoic chambers measuring 2.50 x 1.50 x 1.50 m in which the air was constantly renewed. All measurements were made on male mice weighing 23 ± 2 g. Control C57B1 mice had TRG levels of 1.46 ± 0.06 g/l, control DBA mice had TRG levels of 1.98 ± 0.09 g/l, and control Swiss mice, TRG levels of 1.30 ± 0.11 g/l. At a power density of 12 mW/cm^2, only the C57B1 (2.35 ± 0.11 g/l; 62% increase) and DBA mice (2.95 ± 0.15 g/l; 49% increase) experienced significant ($p<0.001$) increases in TRG levels. The percentage of C57B1 mice with TRG levels higher than the upper limit of the controls was 70%; the corresponding percentage for the DBA mice was 67%. At a power density of 3 mW/cm^2, a significant increase in serum TRG levels was observed only for the C57B1 mice (2.95 ± 0.15 g/l; 43% increase). The percentage of irradiated mice with TRG levels higher than the upper limit of the controls was 65% for the C57B1 mice. It is concluded that, with respect to elevation of TRG levels, different strains of mice vary in their sensitivity to microwaves, and individuals within the strain may also vary in sensitivity.

6113 EFFECT OF MICROWAVES ON BACTERIA, YEAST, AND *DROSOPHILA*. *(Fre.)* Dardalhon, M. (Fondation Curie, Institut du Radium, Section de Biologie, 26, rue d'Ulm, 75005 Paris, France); Averbeck, D. *In: Effets Biologiques des Rayonnements Non Ionisants--Utilisation et Risques Associes.* Proceedings of the Ninth International Congress of the Societe Francaise de Radioprotection. (Nainville-les-Roches, France): pp. 279-299; 1978. (25 refs)

The effect of microwaves on the growth, survival, and mutation frequency of various cultures of *Escherichia coli* and *Saccharomyces cerevisiae* and on the survival, fertility, and appearance of mutations and malformations of wild-type and melanoma tumor-bearing mutant *Drosophila* was investigated. Survival in four types of *E. coli* (wild type, recombinant, and Uvr) and two types of *S. cerevisiae* (wild type and rad) was not affected by exposure to 70-75 GHz (power density, 60 mW/cm^2) or 17 GHz (50 mW/cm^2) for 30 min. A decrease in the growth rate varying from 6-30% was observed in the *E. coli* after 3 hr of irradiation of 70.5 GHz or 73 GHz. Mutation frequency as measured by reversal of tryptophan dependency in *E. coli* and by petite colony formation in *S. cerevisiae* was not increased in colonies subjected to 70-75 GHz for 30-40 min compared with controls; induction of mitotic recombination in *S. cerevisiae* also was not changed in yeast exposed to 17 GHz for 1-24 hr. *S. cerevisiae* showed a slight increase in petite colony mutation after exposure to a combination of 1 hr of 17 GHz microwave radiation and 30 krad of x-radiation. The *Drosophila* experiment included irradiation of eggs, larvae, pupae, and adults. After treatment with 17 GHz, 60 mW/cm^2 for 2-3 hr or 73 GHz, 100 mW/cm^2 for 2 hr, eggs, larvae, and pupae demonstrated only a slight decrease in survival, which was not statistically significant. No mutagenic or teratogenic effects were observed. There was a slight decrease in the number of tumors observed in the mutants (2.66-7.19%). When female *Drosophila*, irradiated for 16 hr or 21 hr with 17 GHz, were crossed with nonirradiated males, a significant increase (30%) in the number of eggs produced was observed. Comparable results were obtained when nonirradiated females were crossed with irradiated males.

6114 A SPECIFIC EFFECT OF THE BIOLOGICAL IMPACT OF MICROWAVES. *(Fre.)* Tchao, Y. H. (Laboratoire d'Opto-Acousto-Electronique de Valenciennes, Laboratoire associe au CNRS 59326 Valenciennes, France); Radziszewski, E.; Sauzin-Monnot, M. J.; Briancon, C.; Wikgren, M. *In: Effets Bio-*

logiques des Rayonnements Non Ionisants--Utilisation et Risques Associes. Proceedings of the Ninth International Congress of the Societe Francaise de Radioprotection. (Nainville-les-Roches, France): pp. 301-313; 1978. (11 refs)

The biologic effects of microwaves (9,300 MHz) from either a continuous power source of 10 W or from a pulsating generator (NARDA model 18 500 B) on the planaria *Dugesia geniocephala* were studied. The planaria were weighed individually and classed in three groups: 3.5-4.4 mg; 4.5-5.4 mg; 5.5-6.4 mg. They were anesthetized with 2.5% chloretone and placed on individual Plexiglas supports. Each planaria was irradiated individually, and 10 planaria were irradiated for each aspect of the experiment. The density of absorbed energy (DAE) was 24 mW/mg for planaria exposed for 1 min to continuous wave microwaves. It was apparent that the electrical field was responsible for the deleterious effects rather than the magnetic field since planaria irradiated parallel to the electrical field experienced almost 100% mortality at 24 hr; mortality was approximately 10% for planaria placed parallel to the magnetic field. Planaria were exposed to a continuous or pulsating wave with DAE of 1-20 mW/mg for periods of 10, 20, and 40 sec, and the head was then severed. For both continuous and pulsating radiation exposure, at all three exposure periods, mortality was greater for head segments than for body segments indicating the higher sensitivity of nervous tissue to microwaves. Planaria regeneration was studied in planaria decapitated and then irradiated 1-7 days later with continuous wave microwaves (DAE of 5.5 mW/mg for 20 sec). Mortality measured at 24 hr and at 7 days showed a relationship to duration of time between decapitation and irradiation with maximum mortality at 4 days. Cells undergoing differentiation were more radiosensitive than undifferentiated cells.

6115 PRELIMINARY RESULTS ON THE STUDY OF EFFECTS OF MICROWAVES ON THE CENTRAL NERVOUS SYSTEM OF A PRIMATE *(MACACA MULATTA).* *(Fre.)* Klein, M. J. (Centre de Recherches de Medecine Aeronautique, 26 Boulevard Victor, 75996 Paris Armees, France); Milhaud, C. L. *In: Effets Biologiques des Rayonnements Non Ionisants--Utilisation et Risques Associes.* Proceedings of the Ninth International Congress of the Societe Francaise de Radioprotection. (Nainville-les-Roches, France): pp. 315-336; 1978. (47 refs)

Thirteen adult or young adult Macaque Rhesus monkeys were studied for effects on the central nervous system and behavior following exposure to microwave irradiation, either whole-body or localized, of varying power density (1.1 mW/cm^2; 3-5 mW/cm^2; 15 mW/cm^2), of different types (9.4 GHz from a pulsating source; 2.45 GHz from a continuous source) and of varying duration (3-25 days). Monkeys were exposed in an anechoic chamber (2 x 2 x 1.8 m) that was ventilated, maintained at temperatures of 20-24 C, and lighted 12 out of 24 hr. The animals were exposed to two different sources of radiation: (1) 9.4 GHz modulated by 1 μsec impulses with a repetition frequency of 570 Hz delivered by a 250-kW generator from an overhead source; and (2) 2.45 GHz from a continuous wave 1.5-kW generator. Radiation reached the animals via a waveguide in the ceiling of the chamber. Six monkeys were subjected to whole-body 9.4 GHz pulsed radiation for 230 hr and to 2.45 GHz continuous wave radiation for 25 days. Two monkeys were irradiated on the head only for 75 hr. One monkey was subjected to discontinuous irradiation of 10 min/day before and after which cerebral temperature measurements were made. Five of this group of monkeys had epidural electrodes implanted prior to radiation. Visual and statistical analysis of electroencephalograms taken daily during a 1-hr stoppage of the generators failed to show any evidence of abnormalities. Cerebral temperature rose 0.5 C maximum in the monkey irradiated intermittently, which was attributed to the thermoresistance of the implanted electrodes. Spontaneous and operant conditioning behavior studies were performed on four monkeys irradiated with 2.45 GHz for 400 hr after a conditioning period of 4 mo. Only one monkey showed changes in spontaneous behavior with development of clonic type uncontrolled motor movements of 2-3 sec, which occurred about 10x/day after the animal had been irradiated for 90 hr. No changes in conditioned behavior occurred (20 tests). No changes in psychologic parameters, triglycerides, or rectal temperature were observed following irradiation.

6116 NONIONIZING RADIATIONAL INJURY OF HUMANS. *(Eng.)* Zaret, M. M. (Zaret Foundation, P.O. Box 388 M, Scarsdale, NY 10583). *In: Effets Biologiques des Rayonnements Non Ionisants--Utilisation et Risques Associes.* Proceedings of the Ninth International Congress of the Societe Francaise de Radioprotection. (Nainville-les-Roches, France): pp. 337-356; 1978. (0 refs)

Clinical and experimental data on nonionizing radiation injury are reviewed with particular emphasis on the inadequacies of existing health standards. For both the visible and invisible portions of the nonionizing radiation spectrum, the vast majority of experimental data on which regulations have been based were derived from acute animal research. However, safety must be determined from different criteria, such as, delayed effects following chronic exposure. Regarding the microwave portion of the nonionizing radiation spectrum, there is clinical evidence to imply that field intensities of about 1 mW/cm^2 can be cataractogenic in man. It has also been shown that microwaves can produce premature or abnormal aging. Other conditions related to microwave exposure include interference with cardiac pacemaker function, hypogonadism, angiitis, adverse transfusion reactions (including death) due to hemolysis of blood warmed by microwaves immediately prior to its use, and injury of the fingers and fingernails among food-preparation employees operating microwave ovens. Weak magnetic fields produced by extremely low frequency signal generators have been associated with elevated serum triglyceride levels and with measurable mentation

deficits. There are also a large number of reports relating immunologic, teratogenic, and carcinogenic effects to the microwave portion of the nonionizing radiation spectrum. Finally, it has been hypothesized that aberrant electronic smog is an etiologic or contributory factor in sudden-infant-death syndrome.

6117 RADIOFREQUENCIES AND HYPERFREQUENCIES: APPLICATIONS AND RISKS. *(Fre.)* Vautrin. (No affiliation given); Caluzade; Cavelier. *In: Effets Biologiques des Rayonnements Non Ionisants--Utilisation et Risques Associes.* Proceedings of the Ninth International Congress of the Societe Francaise de Radioprotection. (Nainville-les-Roches, France): pp. 357-363; 1978. (0 refs)

The potentially harmful effects of exposure to electromagnetic radiation in the high or hyperfrequency range are reviewed in addition to the theoretic aspects of electromagnetic waves. Practical applications are tabulated, giving frequency in MHz and power in kW. Sources of high or hyperfrequency electromagnetic waves already widely in use are radio and television transmitters, radar, industrial and medical machinery, and microwave ovens; under development are methods and machinery for repairing roads, disinfecting water, milk and foodstuffs, and exploding rocks and concrete. Malfunctioning computers can be a source of microwave radiation. Due to a lack of knowledge concerning the nonthermal biologic effects of high and hyperfrequency electromagnetic radiation, internationally acceptable standards for regulation of radiation have not yet been established. A table compares dangerous levels of exposure as defined by the United States, the USSR, and France for workers and the population at large. Methods used to monitor electromagnetic radiation in France are described; the mW/cm^2 after 1 hr of exposure to 18 different industrial and domestic sources of radiation is graphed. Limitation of exposure to radiation under 10 mW/cm^2 is recommended, and methods for reducing exposure, such as, shielding machinery or personnel, are described.

6118 MAGNETIC FIELD EXPOSURE GUIDELINES. *(Eng.)* Alpen, E. L. (Donner Lab., Lawrence Berkeley Lab., Berkeley, CA 94720). *In: Proceedings of the Biomagnetic Effects Workshop, April 6-7, 1978.* Lawrence Berkeley Lab., Univ. California, Berkeley, CA (LBL-7452): pp. 19-26; 1978. (3 refs)

Sources of occupational magnetic field exposure and guidelines for such exposures are reviewed. Magnetic fields of up to 1,000 G, which are accessible to operators, are associated with such old technologies as induction welding, electronic heat-sealing of plastic devices, spot welding, induction furnaces, and other induction-type devices. Among the newer technologies that involve possible hazards from magnetic fields is the superconducting magnet energy storage system. The maximum fields that will be accessible to operators of these systems will be on the order of 200-500 G. Data on the maximum possible exposure to persons who will be in maintenance and operating spaces outside the control room of prototype fusion reactors indicate that the magnetic fields can rise as high as 10 kG with very large gradients; the duration can be quite long (about 30 sec). In the new technology of accelerator operations, bubble chambers involve particularly large magnetic fields; operating personnel could be exposed to anywhere from 6-15 kG for approximately 8-10 min. Currently there are no official magnetic field exposure criteria extant anywhere in the world. Unofficial standards recommended in the USSR for homogeneous fields (direct current) are 300 G (whole body) and 700 G (hands) and for gradient fields (direct current) 500-2,000 G/m (whole body) and 1,000-2,000 G/m (hands). Magnetic field exposure standards are currently in use at two laboratories in the United States. At the National Accelerator Laboratory, the exposure standard is 100 G to 5 kG when work in the area is minimized. A standard of 5-10 kG is set for whole body exposure for up to 1 hr; this can be exceeded with permission of the Senior Radiation Officer. An individual who will be exposed to a field exceeding 10 kG must have the approval of the Senior Radiation Officer. At the Stanford Linear Accelerator facility, the standards for exposure to direct current fields for extended periods are 200 G for the whole body or head and 2,000 G for the arms and hands. For short periods (minutes), the respective standards for whole body or head and arms and hands are 2,000 G and 20,000 G. Although the current unofficial standards contain a wide range of numbers, they differ only by about an order of magnitude.

6119 EXPERIMENT AND THEORY IN LONG RANGE INTERACTIONS OF ELECTROMAGNETIC FIELDS AT BRAIN CELL SURFACES. *(Eng.)* Adey, W. R. (Res. Service 151, Jerry L. Pettis Memorial Veterans Admin. Hosp., Loma Linda, CA 92357). *In: Proceedings of the Biomagnetic Effects Workshop, April 6-7, 1978.* Lawrence Berkeley Lab., Univ. California, Berkeley, CA (LBL-7452): pp. 53-78; 1978. (24 refs)

Experiments and theoretic models dealing with long-range interactions of electromagnetic fields at brain cell surfaces are reviewed. Experiments with animals have indicated that behavior can be modified by the presence of radio signals that are made to resemble, to some degree, the brain's own signaling system. For example, in training and extinction trials with cats exposed to 147-MHz radiowaves (0.8 mW/cm^2) that were amplitude modulated at a frequency of an electroencephalogram rhythm burst in the particular brain structure, the presence of the modulated radio frequency field greatly prolonged the extinction of a learned response. Experiments with isolated neonatal chick forebrain have demonstrated significantly increased calcium efflux under exposure to 450-MHz fields amplitude modulated at 16 Hz when the incident field intensities were in the range of 0.1-1.0 mW/cm^2. Theoretic models that address the question of cooperativity at cell membrane surfaces in relation to the sensing

of weak fields are reviewed. One of the models examined suggests that the membrane surface may be acting as a low pass filter for the transfer of thermal noise. It is suggested that if one looks at the surface of the membrane in the counter-ion layer (within 20-50 A of the surface) it may indeed be functioning as a low pass filter. In both theoretic models and in actual tests, it has been shown that there is a dielectric dispersion with an apparent dielectric constant in excess of 10^6 at frequencies of less than 1.0 kHz in the counter-ion layer, indicating that it is almost an ideal low pass filter. Taking these data and a specific resistance of 300 ohms/cm for the brain, it is calculated that in order to displace ions along the surface, the transfer function for the bulk of thermal noise would be 10^{-8} V/cm. This is exactly the figure that has been indicated as the biologic sensitivity in marine vertebrates. This figure is also within an order of magnitude of the sensitivity observed for the mammalian central nervous system in extremely low frequency experiments, both chemically and behaviorally. Overall, it is concluded that there are special structural organizations in the central nervous system of all vertebrates, and particularly the mammal, that may make them susceptible in subtle ways to environmental electric fields, electromagnetic fields, and to the intrinsic fields in brain tissue.

MEETING ABSTRACTS

6120 FERROMAGNETIC ORIENTATION IN BACTERIA (MEETING ABSTRACT). *(Eng.)* Blakemore, R. (Dept. Microbiology, Univ. New Hampshire, Durham, NH 03824). *In: Proceedings of the Biomagnetic Effects Workshop, April 6-7, 1978.* Lawrence Berkeley Lab., Univ. California, Berkeley, CA (LBL-7452): pp. 6-7; 1978. (3 refs)

Studies of ferromagnetic orientation in bacteria are reviewed. Bacteria that orient and swim in a preferred direction in magnetic fields have been observed in diverse aquatic environments. Electron microscopy of marine and freshwater magnetic bacteria has revealed the presence of intracytoplasmic granules or crystals arranged in clusters or chains and contained within triple-layered membranes. Energy dispersive x-ray analysis revealed iron as the predominant elemental constituent of these particles. A species of magnetic bacterium recently isolated from a swamp retained its magnetism upon repeated transfer in laboratory culture media. Cells of this species contained chains of electron-dense crystals previously described as constituents of magnetic bacteria from mud. Remagnetization of swimming magnetic bacteria has been studied using a critically damped electric circuit capable of producing a magnetic field strength of 0-600 G in the center of two Helmholtz coils. Bacteria were made to swim in a constant, uniform magnetic field ranging from zero to four times that of the local geomagnetic field. The application of a magnetic pulse of sufficient intensity and antiparallel to the direction in which the bacteria were swimming caused the cells to turn around and swim in the opposite direction. To affect turning of 50% of a population of the predominant type from a freshwater swamp, 375-400 G was required. To remagnetize 50% of the predominant form from a marine marsh, 525-550 G was required. Tracks of swimming bacteria have been photographed using timed exposures; the radius of the U-turn resulting from reversing the ambient (orienting) field was essentially the same as that resulting from remagnetizing the bacteria. Moreover, at the intensity required to remagnetize 50% of the population, no cells in the population remained completely depolarized. These results suggest that the bacteria orient through ferromagnetism and exhibit properties characteristic of single magnetic domains. No experimental evidence is presently available to explain why the cell's magnetic movement favors northward and downward motion in the geomagnetic field.

6121 ELECTROMAGNETIC GUIDANCE SYSTEMS IN FISHES (MEETING ABSTRACT). *(Eng.)* Kalmijn, A. J. (Dept. Biology, Woods Hole Oceanographic Inst., Woods Hole, MA 02543). *In: Proceedings of the Biomagnetic Effects Workshop, April 6-7, 1978.* Lawrence Berkeley Lab., Univ. California, Berkeley, CA (LBL-7452): pp. 8-10; 1978. (12 refs)

Electromagnetic guidance systems in fish are discussed. Marine sharks, skates, and rays are extremely sensitive to weak electric fields in their seawater environment. Operating in the frequency range of 0 (direct current) to about 8 Hz, they exhibit biologically meaningful responses to voltage gradients as low as 0.01 μV/cm. These low-level electric fields are detected by the ampullae of Lorenzini, which comprise a delicate sensory system in the protruding snout of the elasmobranch fish. Freshwater stingrays, lower bony fish, catfish, and weakly electric fish also have ampullary receptors, though of much smaller size, which render them sensitive to direct current and low-frequency voltage gradients of 1 μV/cm or slightly less. The ampullary receptors of both marine and freshwater electrosensitive fish have been shown to play an important role in the detection of prey and in spatial orientation. When actively swimming through the earth's magnetic field, sharks, skates, and rays also induce local electric fields of which the voltage gradients depend on the fish's compass heading. Since these fields are strong enough to be detected at swimming speeds of only a few cm/sec, the elasmobranches could very well be endowed with an electromagnetic compass sense. Sharks and rays have been observed to react to non-uniformities in the geomagnetic field, to rest in areas predetermined by the magnetic field direction, and during training experiments to secure food from an enclosure in the east but not to enter a similar enclosure in the west of their tank.