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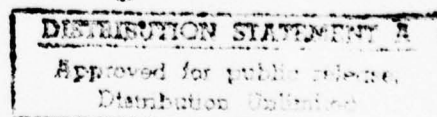
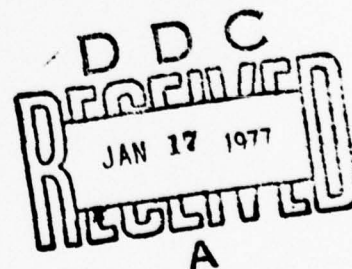
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BIOLOGICAL EFFECTS OF ELECTROMAGNETIC RADIATION

A Digest of Current Literature and a
Forum of Communication

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Literature Selected and Abstracted

by

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PREFACE

Biological Effects of Electromagnetic Radiation is a publication researched and prepared by the Franklin Institute Research Laboratories, Science Information Services Department, under a grant from the U. S. Army Research Office. The grant is co-sponsored by the Bureau of Radiological Health, Food and Drug Administration; Office of Naval Research; U. S. Navy Bureau of Medicine and Surgery; U. S. Air Force School of Aerospace Medicine; and the Walter Reed Army Institute of Research. The U. S. Environmental Protection Agency is cooperating in this project.

Biological Effects of Electromagnetic Radiation serves as a vehicle through which current documentation of research highlights on the biological effects and health implications of nonionizing electromagnetic radiation (microwave and radiofrequency radiation) are compiled, condensed and disseminated on a regular basis. *Biological Effects of Electromagnetic Radiation* is intended to be a highly useful current awareness tool for scientists engaged in research or related activities. The great number and diversity of relevant publications make imperative the availability of this service to persons whose work requires that they keep abreast of current developments in the field.

Biological Effects of Electromagnetic Radiation is published quarterly. Volume I, 1974, consists of three issues, which cover the scientific literature published from July 1973 through December 1974. The first several issues also cover past work of importance. The quarterly issues of Volume II, and future volumes, will include materials received during the preceding three months. Each issue will include news items and announcements, a listing of meetings and conferences, abstracts of current literature, and a directory of current research. Articles carried over because of space limitations and materials for which full text is not available will be included as citations. When available, a special report section, technical note, book review, or topical retrospective literature survey will be included.

ABBREVIATIONS AND ACRONYMS

- A -

A, amp - ampere
ac - alternating current
AF - Air Force
AMP - adenosine monophosphate
ANSI - American National Standards Institute
ARP - adenosine triphosphate

- B -

bpm - beats per minute
BRH - Bureau of Radiological Health
BSA - bovine serum albumin
BSI - British Standards Institute
BUN - blood urea nitrogen

- C -

c - cyclic
C - centigrade
CISPR - Comité International Spécial des Perturbations Radioélectriques (Special International Committee on Radio Interference)
CL - Current Literature
cm, cm² - centimeter, square centimeter
CNS - central nervous system
cps - cycles per second
CR - Current Research
CW - continuous wave

- D -

dB - decibel
dc - direct current
DOD - Department of Defense

- E -

E, \hat{E} - electric field
ECG - electrocardiogram
EEG - electroencephalogram
EHF - extremely high frequency
ELF - extremely low frequency
EM - electromagnetic
EMC - electromagnetic compatibility
EMF - electromagnetic field
EMI - electromagnetic interference
EMP - electromagnetic pulse
EMR - electromagnetic radiation
EPA - Environmental Protection Agency
ES - electrostatic
ESF - electrostatic field

- F -

f - frequency
FDA - Food and Drug Administration
FM - frequency modulation

- G -

g - gram
G - Gauss
GH - growth hormone
GHz - gigahertz

- H -

H, \hat{H} - magnetic field
Hb - hemoglobin
HEW, DHEW - Department of Health, Education and Welfare
HF - high frequency
hr - hour
Hz - hertz

- I -

IEEE - Institute of Electronic and Electrical Engineers
IMPI - International Microwave Power Institute
i.p. - intraperitoneal
IR - infrared
ISM - assigned industrial, scientific and medical frequencies
i.v. - intravenous

- J -

J - joule

- K -

kA - kiloampere
kg - kilogram
kHz - kilohertz
km - kilometer
kV - kilovolt
kW - kilowatt

- L -

l - liter
LDH - lactate dehydrogenase
LF - low frequency

- M -

m, m² - meter, square meter
mA - milliampere
mc - megacycle
MF - medium frequency
mg - milligram
mho - unit of measurement of conductivity
MHz - megahertz
min - minute
ml - milliliter
mm - millimeter
mmho - millimho
mon - month
mW - milliwatt
Mw - megawatt
MW - microwave
mV - millivolt

ABBREVIATIONS AND ACRONYMS

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- N -

NADH - reduced nicotinamide adenine dinucleotide
NBS - National Bureau of Standards
NIH - National Institutes of Health
NIR - nonionizing radiation
nm - nanometer
NMR - nuclear magnetic resonance
nsec - nanosecond
NSF - National Science Foundation
NIOSH - National Institute for Occupational Health
and Safety
NTIS - National Technical Information Service

- O -

ONR - Office of Naval Research
OSHA - Occupational Safety and Health Administration
OTP - U.S. Office of Telecommunications Policy

- P -

P - pulsed
PEMF - pulsed electromagnetic field
PFD - power flux density
PHS - Public Health Service
PMF - permanent magnetic field
pp - pulsed power
pps - pulse per second
PRR - pulse repetition rate
PW - pulsed waves

- R -

R - Roentgen
RBC - red blood cell
RC - resistance-capacitance
RF - radiofrequency
RMF - rotating magnetic field
RNA - ribonucleic acid
rpm - revolutions per minute

- S -

s.c. - subcutaneous
sec - second
SGOT - serum glutamic oxalacetic transaminase
SHF - super high frequency

- T -

TEM - transverse electromagnetic mode

- U -

U - unit, units
UHF - ultra high frequency
USAFSAM - U.S. Air Force School of Aviation Medicine
USDA - U.S. Department of Agriculture
UV - ultraviolet

- V -

V - volt
VA - Veterans Administration
VLF - very low frequency
vol - volume

- W -

W - watt
WBC - white blood cell
WG - waveguide
WHO - World Health Organization
wt - weight

- Y -

yr - year

SYMBOLS

ϵ - dielectric constant
 λ - wavelength
 μ - micro
 σ - specific conductance
 Ω - ohm
 \sim - approximate
 γ - gamma

NEWS ITEMS

CONFERENCE ON BIOLOGIC EFFECTS OF NONIONIZING RADIATION, NEW YORK, 1974

Abstracts of the proceedings of the conference on Biologic Effects of Nonionizing Radiation, which was held by The New York Academy of Sciences on February 12-15, 1974, are included in the Current Literature section of this issue of *Biological Effects of Electromagnetic Radiation Digest* (CL 0480 through CL 0530). The proceedings were published in *Annals of the New York Academy of Sciences*, volume 247, 1975.

MICROWAVE TREATMENT OF BRONCHIAL ASTHMA

V. M. Inyushin, *et al.* have announced a way to treat bronchial asthma by EM irradiation using monochromatic coherent rays on acupuncture skin locations. This method, which lowers undesirable side effects of prolonged irradiation, is based on irradiation of the thorax localization for ten sec to two min at 0.1-20 mV for 10-20 days. *Soviet Inventions Illustrated*, W(11):1, 1975

UTAH BIOENGINEERING NEWSLETTER RESEARCH REPORTS

A research program is underway at the University of Utah to determine the feasibility of reflected and transmitted MW radiation to measure pulmonary parameters. This research is being performed by C. Durney and associates with assistance from Dr. Alan Toronto, Medical Director at Utah Biomedical Test Laboratory.

A research program to determine the therapeutic effects of combined hyperthermia and x-ray radiation treatment for abdominal cancer is being conducted using a special 915 MHz waveguide irradiation apparatus. A liquid crystal fiberoptic temperature probe is invaluable in monitoring and controlling body temperature. Cellular assays are being directed at determining possible thermal enhancements for differential cancer/normal cell destruction.

Utah Bioengineering Newsletter, May, 1975

EPA SEEKING DATA ON HIGH-VOLTAGE LINES

The EPA is collecting data to determine whether or not there is a need to provide radiation standards to protect the public from environmental effects associated with the operation of extremely high voltage (≥ 700 kV) power lines. It is estimated that 10,000 miles of lines at 765 kV or higher will be built in the next 15 yr and system voltages up to 2000 kV are considered feasible. *Mach. Des.* 47(13):18, 1975

ZEUGMATOGRAPHY

Paul C. Lauterbur, University Center at Stony Brook, New York, has invented a process to study tissues in living animals using zeugmatography, a technique in which images are revealed through the interaction of radiowaves and a magnetic field. When small animals are simultaneously exposed to LF radio waves and placed between the poles of a circular magnet, a small fraction of the RF energy is intercepted by the spinning nuclei of hydrogen atoms in the water of the animal tissue. These nuclei glow, and when the transmitter is turned off the glow fades quickly in some organs, slowly in others, and most slowly in malignant tissue. The radio glows can be resolved into images and, by use of a nonuniform magnetic field, may be tuned in and obtained, usually with the help of computer calculations. Equipment will be assembled to project these images on a TV screen with color coding to denote rates at which glows fade. Eventually equipment large enough to accommodate a whole human being and reveal images transparent to x-rays will be available. *Chemistry* 48(6):23-24, 1975

MICROWAVE WORKSHOP

Microwaves as an Adjunct to Cancer Treatment, a workshop arranged by the American Association for the Advancement of Science and the National Cancer Institute, Division of Cancer Treatment, was held at the National Institutes of Health, Bethesda, Maryland, on April 24, 1975. The workshop was chaired by Dr. E. R. Atkinson, with Dr. F. J. Adrian, Dr. J. B. Block, Dr. P. D. deIpolyi, Dr. J. W. Frazier, Dr. B. C. Giovanella, Dr. A. C. Hollinshead, Dr. A. W. Guy, Dr. E. Postow, Dr. H. P. Schwan, Dr. M. Stamm, and Dr. S. J. Webb participating.

ITEMS FROM THE COMMERCE BUSINESS DAILY

○ RESEARCH ON THE EFFECTS OF RADIOFREQUENCY RADIATION.

The Office of Naval Research, Arlington, Virginia, has contracted with Wayne State University, Detroit, Michigan, for the above study. (April 2, 1975)

○ EFFECTS OF MICROWAVE RADIATION ON THE NERVOUS SYSTEM.

The National Institute of Environmental Health Sciences is interested in receiving contract proposals for the above study. (April 25, 1975)

○ AUDITORY NEURAL RESPONSE OF CATS TO LOW-POWER PULSED MICROWAVE IRRADIATION: A PILOT STUDY.

The Environmental Protection Agency proposes to contract with Research Triangle Institute, North Carolina, for the above study. (May 9, 1975)

NEWS ITEMS

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° STUDY ON THE EFFECTS OF MICROWAVE RADIATION OF THE CENTRAL NERVOUS SYSTEM.

The Food and Drug Administration, Rockville, Maryland, has contracted with George Washington University, Washington, D. C., for the above study. (June 6, 1975)

° RESEARCH ON INVESTIGATION OF OCULAR EFFECTS OF CHRONIC EXPOSURE OF PRIMATES TO MICROWAVE RADIATION AT 2.45 GHz.

The U.S. Army Medical Research and Development Command, Washington, D.C., has contracted with Stanford Research Institute, Menlo Park, California, for the above study. (June 11, 1975)

GENETIC MUTATIONS FROM RADIO WAVES?

Sidney Mittler, of Northern Illinois University, has reported results of experiments on fruit flies exposed to radiofrequency radiation. The flies were exposed for 12 hours to radiation of 146 and 29 MHz, frequencies used by ham radio operators. The flies exhibited no genetic damage although they received 600 times the energy that one would be exposed to while standing at the base of a 300 foot antenna of a 50,000 W FM transmitter. *Science News* 107(21): 339, 1975.

THE OFFICE OF RADIATION MEASUREMENTS: A NEW NBS VENTURE

A new Office of Radiation Measurements is being established in the Institute for Basic Standards in NBS. This organization will serve as a means of increasing the contacts between the extensive radiation measurement activities within NBS and the user groups throughout the country. The goals of ORM are fourfold: to promote the effective transfer to federal, state and local regulatory bodies and to the medical community the capability for measurement of radiation at levels that may be biologically hazardous, to assist the technical divisions in monitoring the radiation measurement needs of these groups, to coordinate and assist the technical divisions in their activities undertaken to meet these needs, and to maintain liaison with other organizations with related environmental, energy, health or safety programs.

SOVIET MICROWAVES CAUSE ALARM

Jack Anderson and Les Whitten have reported that the USSR is aiming a microwave beam at the United States believed to keep a round-the-clock watch on U.S. missile sites in the Dakotas. The rays are so powerful that Russians in the area have been moved out and are monitoring the beam by computer from a distance. Just

across the border, Finns have developed very high rates of cancer and heart disease. Ilomantsi, the town nearest the MW station, has the highest rate of any place its size in the world, according to the World Health Organization. Dr. Milton Zaret, who investigated the situation, blamed the installation for the diseases. *Washington Merry-Go-Round*, May 16, 1975

ORGANIZATION OF THE NATIONAL CONFERENCE ON RADIATION MEASUREMENTS

A new National Conference on Radiation Measurements is being formed to provide a forum for discussion, to assist member organizations in their planning, to sponsor technical meetings on radiation measurements, and to promote the development of uniform regulations and procedures. A planning meeting will be held June 11, 1975, and an organizing meeting will be held August 27, 1975 at NBS. Planned participants include the states, federal regulatory agencies, the medical community, industrial organizations, standards writing groups, representatives of the general public, and the National Bureau of Standards.

MEETINGS AND CONFERENCES

**** XXII INTERNATIONAL CONGRESS OF AVIATION AND SPACE MEDICINE

Date: October 7-11, 1974
Place: Beirut, Lebanon
Sponsor: International Academy of Aviation and Space
Medicine
Requests for Information: Dr. F. H. Zebouni, POB 206,
MEA Medical Department, Beirut International Airport,
Lebanon

Selected Bibliography of Papers to be Presented:

PROTECTION AGAINST MICROWAVE HAZARDS. K. D. Wool-
as (Minist. Def., United Kingdom).

**** ELECTROMAGNETIC COMPATIBILITY INTERNATIONAL SYMPOSIUM

Date: July 13-16, 1975
Place: Washington, D.C.
Sponsor: Institute of Electrical and Electronics
Engineers
Requests for Information: W. C. Green, 1625 Eye St.,
NW, Washington, D.C. 20006

**** EUROPEAN MICROWAVE CONFERENCE 1975

Date: September 1-4, 1975
Place: Hamburg, Germany
Sponsor: VDE, in cooperation with the Convention
of National Societies of Electrical Engineers of
Western Europe, IEEE, International Microwave Power
Institute, German National Committee of URSI, and
Microwave Exhibitions and Publishers, Ltd.
Requests for Information: Dr. H. J. Schmitt, Confer-
ence Chairman, Philips Forschungslaboratorium, Vogt
Koellnstrasse 30, D2 Hamburg 54, W. Germany

**** ELECTROMAGNETIC COMPATIBILITY SYMPOSIUM

Date: October 7-9, 1975
Place: San Antonio, Texas
Sponsor: Institute of Electrical and Electronics
Engineers
Requests for Information: W. E. Cory, Southwest Re-
search Institute, Box 28510, San Antonio, Texas

**** USRI/USNC 1975 ANNUAL MEETING

Date: October 20-23, 1975
Place: Boulder, Colorado
Sponsors: URSI, in cooperation with the Institute
of Electrical and Electronics Engineers
Requests for Information: Prof. J. R. Wait, Rm. 242,
RBI, CIRES, University of Colorado, Boulder, Colo-
rado 80302

**** RADIOLOGICAL SOCIETY OF NORTH AMERICA

Date: November 30-December 5, 1975
Place: Chicago, Illinois
Sponsor: Radiological Society of North America
Requests for Information: T. A. Tristan, MD, RSNA

**** INTERNATIONAL MICROWAVE SYMPOSIUM

Date: June 14-16, 1976
Place: Cherry Hill, New Jersey
Sponsor: Institute of Electrical and Electronics
Engineers
Requests for Information: IEEE (tentative)

**** MEASUREMENTS FOR THE SAFE USE OF RADIATION TECHNICAL CONFERENCE

Date: March 1-4, 1976
Place: Gaithersburg laboratory of NBS
Sponsors: Conference of Radiation Control Program
Directors, Health Physics Society, and American
Association of Physicists in Medicine
Requests for Information: J. M. Wyckoff, Radiation
Safety Coordinator, National Bureau of Standards,
Washington, D.C. 20234 (301) 921-2029

**** RADIATION RESEARCH SOCIETY ANNUAL MEETING

Date: May 11-15, 1975
Place: Miami Beach, Florida
Sponsor: Radiation Research Society
Requests for Information: W. C. Dewey, Dept. Rad. and
Rad. Biol., Colorado State University, Fort Collins,
Colorado 80521

Selected Bibliography of Papers to be Presented:

INTERACTION OF DAMAGE DUE TO IONIZING AND NONION-
IZING RADIATION IN CHINESE HAMSTER CELLS. A. Han
(Argonne Natl. Lab., Argonne, Ill.) and M. M. El-
kind.

RADIATION INACTIVATION OF HUMAN LYMPHOCYTES. D.
Kwan (Univ. California, Los Angeles) and A. Nor-
man.

CELL MEMBRANE DAMAGE IN CULTURED MAMMALIAN CELLS
EXPOSED TO ULTRASOUND. B. I. Martins (Lawrence
Berkeley Lab., Berkeley, Calif.), M. R. Raju, T.
L. Hayes, and C. A. Tobias.

MEETINGS AND CONFERENCES

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THE EFFECTS OF MICROWAVES ON THE TRANSPORT OF ASCORBIC ACID IN THE RABBIT LENS. J. R. Rabinowitz (Med. Cent., New York Univ., New York) and R. B. Olcerst.

**** MICROWAVE POWER SYMPOSIUM 1976

Date: July 27-30, 1976

Place: Leuven, Belgium

Sponsor: International Microwave Power Institute

Requests for Information: Robert V. Decareau,
P. O. Box 247, Amherst, New Hampshire 03037

CURRENT LITERATURE

- 0455 NEUROTRANSMITTER CONTENT OF MOUSE BRAIN AFTER INACTIVATION BY MICROWAVE HEATING. (F.) Merritt, J. H. (U.S. Air Force Sch. Aerosp. Med., Brooks Air Force Base, Tex.), M. A. Medina, and J. W. Frazer. *Res. Commun. Chem. Pathol. Pharmacol.* 10(4):751-754, 1975.

Norepinephrine, dopamine, serotonin, 5-hydroxyindoleacetic acid, and homovanillic acid were assayed in mouse brain after rapid MW inactivation of the brain enzymes. Male Swiss mice (20-25 g) were sacrificed in a MW inactivation system (300 msec at 6 kW). Brain temperatures immediately after inactivation were 75 C. Control mice were sacrificed by cervical dislocation. In both cases the brains were removed, homogenized in acidified butanol, and assayed for neurotransmitters and metabolites. The content of the assayed materials was significantly higher in the brain tissue of irradiated mice than in the brains of unirradiated controls: norepinephrine was 1153 ng/g brain tissue in irradiated mice, 436 ng/g in controls; dopamine 1702 ng/g in irradiated mice, 1068 in controls; similar results were obtained for other assayed materials. Thus, values obtained after conventional methods of sacrifice may not reflect *in vivo* concentrations. The increase may represent a neurotransmitter pool with a very rapid turnover rate. (6 references)

- 0456 HUMAN WHOLE-BODY EXPOSURE TO INFRASOUND. (E.) Slarve, R. N. (Aerosp. Med. Res. Lab., Wright-Patterson Air Force Base, Ohio), and D. L. Johnson. *Aviat., Space, Environ. Med.* 46(4): 428-431, 1975.

Recent reports have attributed serious psychophysiological effects to infrasound, low frequency sound in which pressure variations are below 20 Hz. Levels of infrasound which are of practical concern should be determined so that humans may be protected from unnecessary routine exposure. A dynamic pressure chamber (DPC) was constructed in which human whole-body exposure experiments were run. Four normal subjects were chosen for a series of 8 min runs at 120-144 dB and 1-30 Hz. Prior to the run, pre-exposure audiograms were performed and state of health was checked. Three electrodes were placed on the chest, respiration rate was measured and an ECG was obtained. Heart and respiration rate were continuously monitored, and visual and audio contact was maintained. The subject remained seated but performed simple tasks. Post-exposure otoscopic examinations and audiograms were performed. There were no significant changes in hearing threshold levels. Painless pressure buildup was consistently reported, as well as 34/55 observations of chest and/or abdomen vibrations, probably due to direct transmission from DPC surfaces. Voice modulation, which correlated with the vibratory phenomena of the chest, occurred frequently; however, there was no interference with speech understanding. A few episodes of decreased ability to concentrate, drowsiness and time contraction were reported although there was no objective evidence of the primacy of infrasound in this type of response. None

of the effects consistently observed would indicate that infrasound exposures as high as 144 dB are harmful to healthy subjects. (4 references)

- 0457 EFFECT OF ELECTRIC FIELDS ON GROWTH RATE OF EMBRYONIC CHICK TIBIAE IN VITRO. (E.) Watson, J. (Dep. Electr. Eng., Univ. Col., Swansea, Univ. Wales, U.K.), W. G. deHaas, and S. S. Hauser. *Nature* 254(5498):331-332, 1975.

Embryonic chick tibiae grown *in vitro* were subjected to a static, non-varying electric field (1000 V/cm) and a pulsed, transverse electric field (100 V/cm at 1 pulse/sec); gross development was measured. The 8-9-day-old embryos were decapitated and the tibiae excised with one bone serving as experimental material and one as control. The bones were incubated for 9 days. In static field experiments, no significant differences were observed between test and control fractional increases. The pulsed field experiments resulted in clearly significant increases in the ratio of test to control bones (1.12:1). Macroscopic and microscopic studies revealed no differences in growth patterns between the two sets of bones. The conclusion is that the embryonic bone has a transducer mechanism which allows the electric field to interact directly and modify the growth rate of hydroxyapatite since the bones are in a pre-osseous phase. Because only pulsed fields have an effect, repeated cycles of charge separation are involved. (7 references)

- 0458 INTERACTION OF ELECTROMAGNETIC TRANSIENT RADIATION WITH BIOLOGICAL MATERIALS. (E.) Lin, J. C. (Dep. Rehabil. Med., Univ. Washington Sch. Med., Seattle). *IEEE Trans. Electromagn. Compat.* EMC-17(2):93-97, 1975.

The nature of EM pulse interaction with living systems was studied using frequency dependent complex dielectric properties. The problem is formulated in the frequency domain using a mathematical model for a Gaussian pulse impinging normally on a semi-infinite plane layer of muscle material. Results indicate that the incident pulse undergoes severe reflection upon striking the biological medium, and the transmitted pulse amplitude is quite small. For example, for an incident pulse of 50 kV/m, the transmitted pulse strength for a pulse width of 1 usec is 221 V/m. The transmitted pulse is independent of location within the depths (≤ 30 cm) of interest, indicating that the medium exerts no appreciable effect on pulse width for sufficiently narrow pulses. Considerable broadening takes place for longer pulses. (15 references)

- 0459 EFFECTS OF MICROWAVE IRRADIATION ON EMBRYONIC BRAIN TISSUE. (E.) Rioch, D. M. (Inst. Behav. Res., Inc., Silver Spring, Md.). *U.S. Army Res. Off. Rep.*, Contract No. DAHC04 74 C 0004, 1974, 7p.

CURRENT LITERATURE

Biological Effects Electromagnetic
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Experiments were conducted to replicate earlier observations which showed that radiation on the 13th day of gestation stimulated the growth process. Different strains of rats were irradiated in an anechoic chamber and in a MW oven for 20 min to 16 hrs at 5 - 30 mW/cm². Most rats were sacrificed on the 19th day of gestation. All except one group were exposed early in the diurnal cycle between 0700 and 1100 hrs and showed no significant differences between control and exposed fetuses. For the last group, exposed at 1700 hrs or overnight, the average fetus weight was significantly greater than that of the control group ($p \leq 0.005$), with the control group weighing approximately 10% less and brains approximately 10% smaller than experimental rats. Thus, there may be a critical period in the diurnal cycle (circadian rhythm) during which radiation is effective in increasing the growth rate. (4 references)

0460 FISH MUSCLE IN THE FROZEN STATE: TIME DEPENDENCE OF ITS MICROWAVE DIELECTRIC PROPERTIES. (E.) Kent, M. (no affil.). *J. Food Technol.* 10(1):91-102, 1975.

Experiments were performed to determine permittivity and loss in frozen fish muscle at -30 C and 915 MHz and intrinsic attenuation at 9.47 GHz. Measurements at 915 MHz showed that the loss factor changed considerably even with the samples held at a given temperature. At 9.47 GHz, MW attenuation properties of frozen fish muscle exhibited a time dependence, falling in value over periods of 1-3 wk. This reduction in attenuation is due to gradual accretion of ice in the frozen system at the expense of unfrozen water. At least two exponential components were observed in the overall change. Both are thermally activated and the activation energies for the characteristic time constants are in the range 32-49 kJ/mol. This is similar in value to activation energies for diffusion through dehydrated and frozen systems after recalculation of Jason's data for the latter. What is observed is either the diffusion of liquid water through clathrate type ice structures to a point on the surface where crystallization can take place, or diffusion through the surface states of the ice crystals themselves. (12 references)

0461 MICROWAVE DIELECTRIC LOSS OF *Bacillus Subtilis* SPORES IN AQUEOUS SUSPENSIONS. (E.) Ballario, C. (Ist. Fis. Univ., Rome, Italy), A. Bonicontro, and C. Cametti. *J. Colloid Interface Sci.* 51(1):191-195, 1975.

Adjacent to a solid interface, regardless of the nature of the solid substrate, structured elements of water may become stabilized in the sense of acquiring longer average lifetime. Temperature dependent dielectric loss of aqueous suspensions at MW frequencies may be explained by layers of water with different properties than those of bulk water around particles. If this dielectric loss represents an interface phenomenon, similar anomalies

may occur in biological systems. The dielectric loss ϵ'' for aqueous suspensions of *Bacillus subtilis* spores has been measured at 10.0 GHz and 0 - 60 C. A remarkable anomaly in the temperature dependence of ϵ'' for the spore suspensions occurs around 40 - 45 C, essentially due to dipolar loss of the water component. The partial volume of modified water had a different growth rate at different temperatures before the transition region for spore suspensions at different concentrations, indicating that the characteristics observed in the spore suspension depended on geometric parameters rather than the physical or chemical nature of surfaces. Above the transition temperature "bound water" made no contribution to dielectric loss at sufficiently high frequencies. The presence of this structured water has an important role in the properties of biological systems as it may exert a profound influence on the immediate environment of macromolecules and may be responsible for many observed thermal anomalies in biological systems. (11 references)

0462 EFFECTS OF LOW INTENSITY MICROWAVE RADIATION ON MAMMALIAN SERUM PROTEINS. (E.) Cleary, S. F. (Dep. Biophys., Virginia Commonw. Univ., Richmond). *Dep. Army Res. Rep.*, Contract No. DADA 17-72-C-2144, 78p, 1974.

Low intensity, nonlethal, reversible effects of exposure to 1.7 GHz MW radiation were investigated and mechanisms for such effects were determined. Rabbits were exposed to 1.7 GHz MWs at a known intensity for a predetermined period of time. Immediately afterwards rectal temperature was determined. There was no significant difference with variation of radiation frequencies from 1.7 to 2.45 GHz. Lethal rectal temperature elevation for Dutch rabbits exposed to MW radiation was approximately 5 C. The presence of 2 rabbits in the field was found to cause perturbations resulting in a significant increase in energy absorption in the experimental animals. The effect of 1.7 GHz exposure on the duration of sodium pentobarbital induced sleep resulted in a statistically significant decrease in sleeping time for power densities ≥ 10 mW/cm². Measurements of rectal temperatures implied that the MW induced decrease was a function of mean rectal temperature elevation and mean rate of rectal temperature elevation. The temperature increase probably induced redistribution of the anesthetic from the CNS due to an increase in blood flow. The effects of MW exposure and thermal denaturation were compared in *in vivo* and *in vitro* studies of serum proteins using acrylamide gel electrophoresis. It appeared that changes induced by MW radiation are not the same as those resulting from *in vitro* heating to 43, 45, or 50 C. Studies on effects of single exposures to 1.7 GHz radiation on blood chemistries showed that glucose, SGOT, LDH, BUN, uric acid, total protein, inorganic phosphate, total bilirubin, and cholesterol appeared to be affected; transient alterations were elicited by exposure at 25, 20, and 5 mW/cm², although few differences were statistically significant. (No references)

- 0463 SOME RECENT TRENDS IN EMC TESTS AND MEASUREMENTS. (E.) Lambdin, W. S. (Electrometrics, Div. Penril Corp., Amsterdam, N.Y.). *Microwave J.* (4):49-51, 1975.

A new product is tested for EMC to determine its suitability for entry into the EM environment. This testing is concerned with: (1) emissions from the product which must be controlled to restrict or eliminate interference with other equipment, and (2) susceptibility of the product to emissions levels expected from already operational equipment. There are 2 sets of standards set up, MIL-STD-461/2 and CISPR, which are not compatible and normally require quite different instrumentation. A calibrated sensor for emissions testing is connected to an interference analyzer for the simplest measurements; to this an X-Y plotter, a programmer, a CRT Spectrum Display Module and a digital computer may be added for more automation. Ultimately this handles 20 Hz to 1 GHz and 1 GHz to 12.4/18 GHz systems and may be used for the most advanced MIL-STD measurements. However, it cannot make CISPR measurements, which must be linear, unless it is modified. This is done by adding a Metering Module which automatically splits the radiation into channels required by CISPR. Thus, at the same time a CISPR reading is made, the peak level is registered by the Interference Analyzer for MIL-STD use. (No references)

- 0464 GENERAL BIOLOGICAL AND EMBRYOTROPIC EFFECTS OF PERMANENT MAGNETIC FIELD. (Rus.) Perepechin, E. A. (N.P. Ogarev Mordva University, Saransk, USSR), V. M. Dubova, L. N. Semenov and T. G. Knyazeva. *Gig. Sanit.* (9):23-26, 1974.

The effect of PMF on the generative function was studied in 60 180-240 g pregnant Wistar rats and 423 embryos exposed to 21.01 ± 0.94 kA/m and 2.40 ± 0.47 kA/m fields in the first series of experiments and 8.12 ± 0.29 kA/m fields in the second (fields most frequently present under industrial conditions). The rats were exposed for 2 hr daily through the entire pregnancy. To study the embryotropic action of PMF, measurements were made of fertility, pre-implantation destruction of oviducts, postimplantation embryonal mortality, the weight and length of the embryos and placentas, and organ and skeletal deformities. Exposure to 21.01 kA/m resulted in higher embryonal mortality, individual cases of deformity and greater incidence of tissue hemorrhage (32.55% in the controls and 58% in the experiment), pulmonary hemorrhage (13.95% and 38.7%, resp.), and hepatic hemorrhage (2.33% and 22.58%). In the second series, embryotropic effect of PMF involved higher postimplantation mortality and slower embryonal development. The general biological effect of PMF consisted of the changes in the composition of total proteins and protein fraction ratios in the serum. (3 references)

- 0465 AVOIDANCE BY RATS OF ILLUMINATION WITH LOW POWER NONIONIZING ELECTROMAGNETIC ENERGY. (E.) Frey, A. H. (Randomline, Inc., Huntington Val-

ley, Pa.) and S. R. Feld. *J. Comp. Physiol. Psychol.* 89(2):183-188, 1975.

To determine the motivation properties of MWs at low average power densities, Sprague-Dawley rats were exposed to sham illumination or to pulsed 1.2 GHz energy (30 μ sec pulses, 100 pulses/sec). Pulse-illuminated animals spent significantly less time (29%) in halves of shuttle boxes that were not shielded from the 1.2 GHz radiation than did sham-illuminated rats (57%). Over 7 days of testing, the respective proportions of time spent in the illuminated side within the first 15 min were 32% and 54% for experimental and control groups, resp. Boxes with unshielded halves illuminated by an average power density of 0.4 mW/cm² (133 mW/cm² peak power density) produced an aversion in experimental animals similar to that induced by boxes in which the average power density in the unshielded half was 0.9 mW/cm² (300 mW/cm² peak power density). In a second experiment, the energy was presented both continuously and in pulse-modulated form, i.e., 0.5 msec exponentially decaying pulses at 1000 pps. The average power density of the CW energy was 2.4 mW/cm² and the average power density of the pulse-modulated energy was 0.2 mW/cm²; the peak power density of the modulated energy was 2.1 mW/cm². The rats avoided the pulsed energy but not the CW energy; the difference between the two groups was significant in the last two sessions of a four-session sequence. In these sessions, the pulse illuminated rats averaged 30% of their time in the unshielded halves of shuttle boxes compared with 64% for the CW-illuminated animals. These behavioral observations are in agreement with a physiological study showing that pulsed, but not CW, energy significantly affected fluorescent dye-complex penetrability of the brain barriers of the diencephalon. (12 references)

- 0466 RADIOFREQUENCY AND MICROWAVE RADIATION LEVELS RESULTING FROM MAN-MADE SOURCES IN THE WASHINGTON, D.C. AREA. (E.) Smith, S. W. (Div. Electronic Products, Bur. Radiol. Hlth., Rockville, Md.) and D. G. Brown. *DHEW Publ. No. (FDA) 72-8105*, BRH Pub. No. BRH/DEP 72-5, 56p., Nov. 1971.

During the summer of 1969, man-made radiation levels from 20 Hz to 10 GHz were made at 10 scattered sites from 20 Hz to 10 GHz were measured at 10 scattered sites within a 25 mile radius of Washington, D.C. The lyzed; a summation of power densities from narrow-band sources was made of four biologically relevant portions of the total spectrum measured: less than 400 MHz, 400-1000, 1000-3000, and 3000-10,000. The peak ambient radiation measured approached a maximum of 10^{-2} mW/cm² (10^{-3} mW/cm² excluding high-powered, low-duty-cycle, pulsed radar signals). The average background thus is at least two to three orders of magnitude less than any published U.S. recommendations for exposure to RF radiation. Almost all the power density measured could be attributed to commercial broadcasting and/or high-powered radar installations in close proximity to the monitoring site. On the basis of these results, it is recommended that no further broadband environmental surveys be carried out unless prior calculations indi-

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cate their need. Individual AM and FM radio and VHF, UHF, and radar transmitters, however, should be closely monitored to determine exposure levels at populated sites in proximate areas. (13 references)

0467 EXPERIMENTAL STUDIES CONCERNING THE INFLUENCE OF THE MAGNETIC FIELD ON THE BLOOD.

(*Rum.*) Savciuk, N. (I. I. Pechnikov State Univ., Odessa, USSR), T. Soldatenko, and O. Savciuk. *Igiena* 23(2):107-110, 1974.

After 5 days of exposure to a magnetic field, test animals showed a fall in hemoglobin concentration by 11.8%, increase in number of erythrocytes (15.3%), and decrease in erythrocyte sedimentation rate. Longer exposure resulted in a markedly shorter coagulation rate and, after 15 days, coagulation took place instantly, erythrocyte sedimentation rate was 3 times as short as controls, the number of lymphocytes was reduced by 12.8%, eosinophils by 8%, and neutrophil granulocytes by 10%. The influence of the low intensity magnetic field and prolonged action thus resulted in changes of the blood composition and coagulation rate and changes in cholinesterase activity of the brain. (No references)

0468 ON THE CEREBRAL AND PERIPHERAL CIRCULATION IN PERSONS DEALING WITH SOURCES OF ULTRA-HIGH RADIO-FREQUENCIES, BASED ON THE RESULTS OF RHEOGRAPHIC INVESTIGATIONS. (*Rus.*) Yadrintsev, V. A. (Inst. Ind. Hyg. Occupational Health, Moscow, USSR). *Gig. Tr. Prof. Zabol.* (2):18-21, 1975.

A general clinical examination and an investigation into the cerebral and peripheral circulation using rheovasoenkephalography and rheoencephalography were carried out in persons exposed to ultrahigh radio frequencies. Hemodynamic disturbances of the peripheral circulation, lability of pulse filling, and increased resilient-viscous properties of the finger vessels were found. Hemodynamic indices of the vessels in the brain, forearms and shins remained unchanged. Deviations were more pronounced in persons with vegeto-vasal disorders. Thus, rheographic characteristics of hemodynamic shifts may be used for objective evaluation of functional deviations in health status of ultrahigh radiofrequency operators. (12 references)

0469 THE EFFECT OF SUPERHIGH FREQUENCY FIELDS OF VARIOUS INTENSITIES UPON THE BALANCE AND INTERORGAN METABOLISM OF COPPER, MANGANESE, MOLYBDENUM AND NICKEL IN THE ORGANISM OF EXPERIMENTAL ANIMALS. (*Rus.*) Gabovich, R. D. (Kiev Med. Inst., USSR), A. A. Minkh, and I. A. Mikhalyuk. *Vestn. Akad. Med. Nauk SSSR* (3):16-22, 1975.

A wide spectrum of biological effects were noted in albino rats exposed to SHF fields of various intensities. Changes were noted at very low density

(10 $\mu\text{V}/\text{cm}^2$) and reliable changes indicated by homeostatic disturbances were observed under higher SHF field densities. Exposure caused shifts in balance and inter-organ distribution of trace elements such as copper, manganese, molybdenum and nickel, and changes in metabolism of the trace metals. (8 references)

0470 THE USE OF AN AUTOMATED POPULATION DATA BASE IN POPULATION EXPOSURE CALCULATIONS.

(*E.*) Athey, T. W. (EPA, Off. Radiat. Programs, Silver Spring, Md.), R. A. Tell, and D. E. Janes. *Symposium on Population Exposures* (J. C. Hart, R. H. Ritchie, and B. S. Varnadore, Ed.), pp. 29-36, October, 1974.

The assessment of potential hazard to the population from a source in the environment often requires a knowledge of the specific geographic population distribution around the source. Thus, the EPA Office of Radiation Programs has adapted a computer program package and data base for use in population exposure problems in ionizing and nonionizing radiation areas. The data base consisted of the U.S. Census Bureau Master Enumeration District List with coordinates. The programs generate the total population within selected distances and angular sectors from a reference point designated by its geographic coordinates. Alternately, the programs can be used as subroutines to make available to another program the distance and bearing of each census enumeration district, in a selected region, from a reference point. The potential applications of this population distribution system to exposure problems include single-source discharge from facilities in the nuclear fuel cycle and exposure from nonionizing radiation sources such as radio, television, radar, and microwave transmitters. The population exposure from AM radio standard broadcast stations in the Baltimore-Washington area is discussed in detail. Preliminary measurements around a 50 kW station showed values of 8-12 V/m at 0.1 mile or less; it was estimated that about 3000 persons are exposed at levels of 5-10 V/m. The Russian standard for 0.1-1.5 MHz is 20 V/m³, which probably should not be exceeded by single 50 kW stations. (3 references)

0471 BIOMEDICAL EVALUATION OF LOW FREQUENCY (LONG WAVE) ELECTROMAGNETIC RADIATION ASSOCIATED WITH ELECTRIC POWER TRANSMISSION. (*E.*) Pogrund, R. S. (Sch. Public Health, Univ. Illinois Med. Cent., Chicago). *Symposium on Population Exposures* (J. C. Hart, R. H. Ritchie, and B. S. Varnadore, Ed.), pp. 395-404, October, 1974.

Considerable scientific attention has focused on the possible hazards to human health from such sources of electric power as nuclear and fossil fuels. These hazards have been associated with the release of ionizing radiation during normal reactor operation or accident, as well as inhalation of gaseous and particulate effluents during the burning of fossil fuels. Serious attention should also be given to

the biologic effects of ELF (45-74 Hz) EM radiation associated with electric power transmission. Future generators and transmitters of electrical power may approach the dimensions of the U.S. Navy's Sanguine system, which was to have been a single transmitter complex with a capability for communicating with submarines at operating ocean depths. At the Sanguine frequency of 45 Hz, with free space wavelengths of 6600 km, the radiated ELF signal could penetrate the ocean depth without significant attenuation. A review of biomedical and psychophysiological data shows subtle ELF effects on populations at risk due to residential proximity to transmission lines, or to genetic susceptibility. The effect is both frequency dependent in the EEG range of modulation wavelengths (1-30 Hz) and resonant at small power densities (pulsed or continuous). While the primary effect is on the central nervous system, the exact mechanism of action is assumed to exist at the biochemical molecular level. Human and animal exposures to these energies produce changes in EEG and conditioned reflexes; changes in sensitivity to light, sound, and olfactory stimuli; and cerebral cortex biocurrents. VLF, UHF, VHF, and ELF EM radiation effects are summarized in a table that shows, for each observed effect, frequency, field strength or power density, and references or investigators. (22 references)

0472 TEMPERATURE DISTRIBUTION PRODUCED IN MODELS BY THREE MICROWAVE APPLICATORS AT 433.92 MEGAHERTZ. (E.) Lehmann, J. F. (Dep. Rehabil. Med., Univ. Washington, Seattle), A. W. Guy, J. B. Stonebridge, C. G. Warren and B. J. DeLateur. *Arch. Phys. Med. Rehabil.* 56(4):145-151, 1975.

Temperature distributions produced in phantom models by diathermy applicators operating at the nonapproved frequency of 433.92 MHz and by an experimental cooled contact applicator operating at 915 MHz were compared. The 433.92 MHz applicators were the Rundfeldstahler, a capacity loaded dipole designed for localized treatment; the Langfeldstrahler, which can be applied parallel to the back musculature and spine or parallel to limb segments such as thighs; and the Pyrador, designed for application across the back, buttocks, chest, and abdomen. The specially designed direct contact applicator with surface cooling elevated deep muscle temperatures as effectively as the Rundfeldstrahler in spite of the better penetration of energy at the lower frequency. The Pyrador and the Langfeldstrahler, the largest of the applicators operating at 433.92 MHz, do not appear to offer any advantage over existing diathermy equipment. The highest temperatures produced with these applicators were at the fat-muscle-interface. (18 references)

0473 BIOLOGICAL INTERACTIONS BETWEEN RADIOFREQUENCY ELECTROMAGNETIC WAVES AND IONIZING RADIATION. (E.) Davydov, B. I. (no affil.), V. V. Antipov and V. S. Tikhonchuk. *Kosm. Issled.* 12(1):129-133, 1974.

Mortality, life span, and changes in body wt and leukocyte count were studied in female mice exposed to an SHF field ($\lambda = 12.6$ cm) for 10 days at power flux densities (PFD) of 10, 20, 40, and 100 mV/cm² for 40, 20, 10, and 4 min, resp., followed by ⁶⁰Co irradiation at 400-900 R (25 R/min) or 1000-20,000 R (300 R/min). Preliminary exposure to the SHF field (20 mV/cm² and above) before γ irradiation reduced the median life span of animals; the effect was greatest at 100 mV/cm² and was diminished at increasing doses of γ irradiation. The reduction in median life span induced by consecutive MW and γ irradiation occurred at doses causing damage to the hematopoietic system. Synergism between non-ionizing and ionizing irradiation was not found at dose levels reflecting lesions of the gastrointestinal tract. Investigation of the median lethal dose (SHF + γ) as a function of PFD suggested that at a PFD of 40 mV/cm², the dose of ionizing radiation should be about 100 R less. This hypothesis was confirmed by experiments in which animals were exposed to SHF + 400 R γ irradiation or to 500 R γ irradiation alone. Under both conditions, survival dynamics were virtually identical over a 22 month period. Exposure to the SHF field stimulated wt gain and caused marked fluctuations in leukocyte count. The increase in wt can be regarded as a manifestation of disfunction of the endocrine glands, especially of the hypothalamo-hypophyseal system, rather than as an adaptive reaction. The effect on leukocyte count can be attributed to the appearance of autonomic and hormonal instability. These findings demonstrate that EM waves and ionizing radiation have a synergic effect on the hematopoietic system. (17 references)

0474 PRELIMINARY REPORT: MICROWAVE FIXATION OF HUMAN TISSUES. (E.) Gordon, H. W. (Univ. California Irvine Sch. Med., Irvine), and E. J. Daniel. *Am. J. Med. Technol.* 40(10):441-442, 1974.

Substitution of MW radiation for routine fixation in 10% formalin effectively reduced the elapsed time between tissue selection and microscopic examination. Blocks of 1.0 x 1.5 x 0.5 cm lung, heart, liver, kidney, spleen, and skeletal muscle human autopsy tissue were exposed to MWs from a commercial MW oven in air, saline, water, 10% formalin, and Zenker's solution for 15 sec to 3 min. The experimental tissues were then processed omitting formalin but using conventional procedures otherwise. Control tissues were conventionally processed. Tissues exposed in water, saline, and 10% formalin showed an absence of shrinkage and surface distortion and an increase in stain contrast. Cytological preservation was excellent, with good preservation of nuclear membranes, adequately clumped chromatin, and well defined cellular membranes. The experimental tissues were rated equal to or superior to chemically fixed specimens. An exposure time of 30-45 sec in 300 ml fluid produced formalin equivalent fixation without altering criteria for establishing malignancy. MW radiation must take place in a fluid medium to assure artifact-free tissue. The major

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advantage is a marked reduction in time required for fixation of tissues prior to dehydration and hardening. (3 references)

0475 ARTIFICIAL VISION PROGRESSES. (E.) Ivall, T. E. (Ed., *Wireless World*). *Wireless World* 81(1472):156-158, 1975.

Design improvements in the Medical Research Council's microwave implant for the blind are reported. The principle of this visual prosthesis is to stimulate directly a large number of points on the visual cortex of the brain of a person who has become blind, for example, through damage to the optic nerve. The patient 'sees' spots of lights (phosphenes) which are fixed in the visual field and which can be arranged into meaningful patterns by suitably organizing the electric stimulation. The stimulation is applied by 500 usec pulses of current fed to electrodes mounted in silicone rubber cups in the two occipital lobes of the brain. To provide more stimulation points and to reduce the size of the implant, the hermetic sealing of logic units containing transistor and diode AND gates was replaced by encapsulation with silicone rubber adhesive. With this encapsulation logic packages containing nineteen AND gates (as against the previous twenty) have been produced measuring only 26 mm x 7 mm x 3 mm. The smaller size of the package allows more logic units to be used (sixteen instead of nine); these will be fed with d.c. pulses from 16 row receivers and 19 column receivers, giving 16 x 19 unique pairs of receivers on the matrix and therefore allowing 304 stimulating electrodes. The number of stimulation points will be quadrupled in the new implant. Other improvements include thick-film logic circuits and the use of tantalum electrodes coated with tantalum pentoxide. With this coating, the capacitor and stimulating electrode are combined into one. (5 references)

0476 MICROWAVES IN RADIOTHERAPY OF TUMORS - ALTERNATIVE TO HEAVY PARTICLES? (E.) Dietzel, F. (Cent. Radiol., Justus Liebig Univ., Giessen, Germany), D. Ringleb, U. Schneider, and H. Wricke. *Strahlentherapie* 149(4):438-441, 1975.

MWs used in combination with sparsely ionizing radiation cause an increase in radiosensitivity in treatment of tumors. The therapeutic effect was tested on an euoxic tumor (mice testicles) and a tumor containing parts of hypoxic cells (solid tumor of Erlich). 490 NMRI male mice testicles were irradiated with 120 rd and 340 solid Ehrlich neck tumors (1 ml tumor vol) were irradiated with 2000 R. Both were immediately followed by heating with MWs (461.04 MHz) to 40-43 C. The combined treatment was evaluated 20 days after therapy. Neither group was affected by heating to 40-41 C; however, heating to 42-43 C led to significant weight reduction of both testicles and tumor. In combination with x-ray treatment, increased sensitivity developed in the tumor at 40-41 C, but not in the

testicles. The temperature enhancement ratio is not a linear function of the temperature. Suitable combinations of UHF and sparsely ionizing radiation could replace therapeutic methods with heavy particles in the future. (13 references)

0477 MITOTIC DELAY IN THE SLIME MOULD *Physarum polycephalum* INDUCED BY LOW INTENSITY 60 AND 75 Hz ELECTROMAGNETIC FIELDS. (E.) Marron, M. T. (Div. Sci., Univ. Wisconsin-Parkside, Kenosha), E. M. Goodman, and B. Greenebaum. *Nature* 254(5495): 66-67, 1975.

The effects of low frequency EMFs on the mitotic cycle of the myxomycete *Physarum polycephalum* were examined. Crossed electric and magnetic fields alternating in phase at 60 or 75 Hz at levels of 0.7 V/m and 2.0 gauss, corresponding to fields generated by the U. S. Navy's proposed Project Sanguine communications antenna, were used. A significant mitotic delay became evident after 80-100 days in a 75 Hz EMF. After removal from the field the delay persisted from 30-60 days during which time the mitotic interval converged with that of the control. No significant delay was observed in cultures exposed to weaker 75 Hz EMFs (0.15 V/m, 0.4 gauss) for 200 days. Thus, low level EMFs can influence biological systems; the delay in mitotic cycle shows up only after long exposure periods and does not disappear immediately after removal from the EMF. (9 references)

0478 ELECTROMAGNETIC FIELDS AND SKIN WOUND REPAIR. (E.) Romero-Sierra, C. (Dep. Anat., Queen's Univ., Kingston, Canada), S. Halter, J. A. Tanner, M. W. Roomi, and D. Crabtree. *J. Microwave Power*, 10(1):59-70, 1975.

Experiments were set up to see whether EM nonionizing energy, which stimulates and enhances collagen production in tissue, has a beneficial effect in wound repair. Two sets of experiments were performed. In the first, 2 groups of Sprague-Dawley rats were given 1.5 cm incisions in their backs. The wounds were pretreated with 2 drops of either saline or histamine diphosphate (1.0 mg/ml). Half of each group was exposed to a VHF (27 MHz) field for 15 min while edges of the wound were apposed by manual pressure. Tissues were examined microscopically after 12, 24, and 72 hrs. Marked differences were noted after 12 hrs: In control groups, distance between edges of the wound was much greater than in the test group and the only sign of organization was infiltration of acute inflammatory cells. In the irradiated test groups the wound area was difficult to identify. Wounds treated with the EM field had less of a polymorphonuclear infiltrate and more fibroblasts and macrophages in the incisions suggesting these were healing 24 hr ahead of the unexposed controls. The most efficient wound treatment was histamine plus irradiation, with saline plus irradiation, histamine, and saline successively less effective. The greatest effort occurs within 12 hrs of treatment. In the second experiment, ten

9-11-month-old beagle dogs were given a single 2.5 cm incision in the right foreleg. In 5 days skin was removed from the wound area and tested for tensile strength. The average value for test dogs was 530 g vs 141 g for controls and the cosmetic appearance of the wounds were consistently superior in test dogs. Thus, wounds treated with radiation heal more quickly, are stronger, are superior cosmetically and leave a smaller scar. (5 references)

0479 EXPOSURE OF RABBIT ERYTHROCYTES TO MICRO-WAVE RADIATION. (E.) Hamrick, P. E. (Nat'l. Inst. Environ. Health Sci., Research Triangle Park, N.C.) and J. G. Zinkl. *Radiat. Res.* 62(1):164-168, 1975.

Rabbit erythrocytes were exposed to MW radiation at 2450 and 3000 MHz (CW) in an attempt to duplicate reported changes in the erythrocyte membrane permeability to potassium and changes in osmotic resistance. At 2450 MHz, 1-4 hr exposures were made at intensities of 4, 10, and 75 mW/cm² with absorbed power densities of 3, 7.6, and 57 mW/g, resp. At 3000 MHz, the erythrocytes were exposed for 1 or 3 hr to 5 mW/cm² (5.2 mW/g absorbed power). The suspending medium was buffered saline with or without glucose at 2450 MHz and unbuffered saline at 3000 MHz. Results of all experiments showed no significant difference between exposed and control erythrocyte suspensions in either potassium efflux or in osmotic resistance. (4 references)

SOURCE: Proceedings of the conference entitled Biologic Effects of Nonionizing Radiation sponsored by The New York Academy of Sciences, February 12-15, 1974.

0480 OVERVIEW OF ELECTROMAGNETIC RADIATION RESEARCH: PAST, PRESENT, AND FUTURE. (E.) Tyler, P. E. (EMR Proj. Off., Dep. Navy., Washington, D.C.). *Ann. N. Y. Acad. Sci.* 247, 6-14, 1975.

The historical irregularity of interest and active research in biological effects of EM radiation since its discovery in 1888 are reviewed. The contemporary technological advances and the use of EMR in medicine, industry, research, communications, military systems, and the home; concern with the environment; and recent legislation on health and safety have stimulated the rebirth of biological research in EM radiation. The role of OTP in reviewing, advising, and making recommendations on the potential problems associated with the use of the EM spectrum are discussed. Although most current research is federally funded, it may be unfortunate that there is no single source of major funding since there are many other projects of higher priority within each agency. The nonthermal/thermal discussions should be dropped and instead interest should be focused on the energy absorbed and the presence of a specific field intensity. New approaches are needed. The accumulating evidence that the magnetic component may be of greater significance than previously thought should be studied; as frequency decreases, in the low MHz to kHz range, the magnetic portion may become the major

portion. Modulation is another area only recently believed to be important, and knowledge of the possible additive or synergistic effects of multiple frequencies or other agents requires added attention. Genetic effects of EM radiation are also a critical, unanswered question, and their effects on growth and development of organisms is of related importance. Effects upon the CNS, cataractogenesis, and the problem of dosimetry, densitometry, and measurement are other areas for concerted research. As the Richmond Symposium, held in Richmond, Va., in 1969 pointed the way for subsequent research, the N. Y. Academy of Sciences Conference on the Biologic Effects of Nonionizing Radiation will spotlight the research needed in ensuing years. (25 references)

Part I. Effects on the Nervous System

0481 INTRODUCTION: EFFECTS OF ELECTROMAGNETIC RADIATION ON THE NERVOUS SYSTEM. (E.) Adey, W. R. (Brain Res. Inst., Univ. California, Los Angeles). *Ann. N. Y. Acad. Sci.* 247, 15-20, 1975.

It is suggested that EMR may be an important tool to be used in unraveling the problems of structural and functional organization of the brain. Far beyond the phenomenological effects currently studied, proper research with NIR may give information about transmission, transaction, storage, and retrieval in brain tissue. Interactions with the mammalian CNS can be produced by oscillating electric and EM fields with temperature changes of < 0.1 C, far below natural perturbations in brain temperature. Responsiveness to weak EM fields is due to the collective properties of the cellular elements which may not be discernable in the separate behavior of individual elements. The brain as a whole may react to stimulation much smaller than that which occurs in post-synaptic excitation and may be represented as a hierarchic model. Molecular events at a membrane surface may influence the excitability of a particular neuron which in turn influences other neurons through a conduction process, producing a volume-conducted slow-wave field. A new awareness of the stepwise processes which initiate excitation will lead to further research on transactions of the brain. (31 references)

0482 BIOCHEMICAL AND NEUROENDOCRINE ASPECTS OF EXPOSURE TO MICROWAVES. (E.) Michaelson, S. M. (Dep. Radiat. Biol. Biophys., Sch. Med. Dent., Univ. Rochester, N. Y.), W. M. Houk, N. J. A. Lebeda, S-T. Lu, and R. L. Magin. *Ann. N. Y. Acad. Sci.* 247, 21-45, 1975.

The neuroendocrine system forms a sensitive mode to analyze responses of the endocrine system and higher CNS centers under the influence of environmental changes and readjustments of the organism. Alterations in the secretory levels of the pituitary gland, adrenal cortex, thyroid gland, and gonads will occur in response to MW exposure at some time/intensity relationship. A review and analysis of the literature on hypothalamic, hypophysial, thyroid and

adrenal effects is presented in this paper. In addition, in an effort to synthesize previously reported effects of MW exposure, preliminary experiments are reported. Rats and dogs were irradiated with whole body and local CW MWs at 2450 MHz to resolve certain thresholds for MW-neuroendocrine interaction and to study target organ and metabolic responses to short term medium and high intensity radiation. Four hundred Long-Evans rats were exposed to 150 min irradiation after adaptation for 2 wks. They were then weighed, decapitated, exsanguinated and colonic temperature was taken. All levels of exposure (9, 18, and 36 mW/cm²) indicated a distinct temperature rise; preexposure temperature levels were reached 60 min after termination of radiation. Serum GH dropped within 60 min of irradiation with 36 mW/cm², associated with a peak in the rise of mean whole body temperature to 40.9 C. This is compatible with a general stress reaction. Serum glucose, triglyceride, and cholesterol levels were not grossly affected. In the mammal, a principal mechanism for regulating thermal inputs is adjustment of the cardiovascular system; studies are being performed to relate neuroendocrine function and cardiovascular response to MW exposure. In studying endocrine function, all interdependent components of the system are exposed to variable degrees simultaneously; it is hard to relate effects to a particular sensitivity of any component or group of components within the system. The nature of MW interactions is not known but there are indications that irradiation can act as a 'stressor,' altering homeostasis. There is a pattern of neuroendocrine involvement in the many physiologic adjustments of the organism relative to increased body temperature or alterations in thermal gradients within the body. (79 references)

0483 EFFECTS OF LOW-INTENSITY MICROWAVES ON ISOLATED NEURONS. (E.) Wachtel, H. (Dep. Biomed. Eng. Electr. Eng., Duke Univ., Durham, N. C.), R. Seaman, and W. Joines. *Ann. N. Y. Acad. Sci.* 247, 46-62, 1975.

Ganglia from the marine gastropod *Aplysia*, which are smaller than the shortest length MW employed, were studied to determine the effects of MWs on isolated nerve cells. A ganglion was placed within a MW stripline and intracellular glass microelectrodes were used to record the electric activity of individual neurons before, during, and after irradiation. Because of small sample size and simple geometry of the stripline the absorbed power could be calculated from the total incident power. The most striking effects found were changes in firing patterns of pacemaker neurons, both beating pacemakers with regular interspike intervals (ISI) and bursting pacemakers with regular interburst intervals (IBI). In *Aplysia* the ISI fires very regularly (< 10% variation) so an induced change is easily distinguished and is probably of "informational" significance to the neuron. ISI and IBI alterations were induced by MW intensities of 5 mW/cm² or less. When CW and PW (1-5 kHz, 10 usec pulse width) radiation of the same average power were compared, no significant differences were detected although preliminary results in-

dicated that pulses of 10-100 msec may have increased efficacy in synchronizing firing patterns. No differences were noted in changing from 1.5 to 2.45 GHz frequency. When irradiation was compared to heating the samples, the effect on ISI and IBI seemed to be much greater for convective heating. No significant differences in action potential size, duration or shape, or in resting potentials or conductance were noted on irradiation. It is suggested that MWs may act to change the depolarization rate of the neural membrane toward the firing level as the current density produced is 10³ times as great as the polarizing current density needed to produce an effect on firing patterns. While the effects noted may not be harmful they would be disruptive of ongoing information handling processes if they occurred in an intact nervous system. (11 references)

0484 SOME EFFECTS OF ELECTROMAGNETIC RADIATION ON THE BRAIN AND SPINAL CORD OF CATS. (E.) Taylor, E. M. (Dep. Rehabil. Med., Sch. Med., Univ. Washington, Seattle) and B. T. Ashleman. *Ann. N. Y. Acad. Sci.* 247, 63-73, 1975.

Spinal cords from 49 cats (3.0 kg) were used to study effects of EMR and to evaluate effects by parallel heating and cooling. The spinal cord was chosen because of its high resolution, identifiability of active components, small aggregates of active elements, and accessibility to experimental procedures. The cats were anesthetized, an extensive laminectomy was performed, the cord was exposed, and a nerve root pair was chosen. The ventral root of this pair was elevated and sectioned. Spinal cord activity, detected at the ventral root, was recorded electronically. EM radiation (CW) at 2450 MHz, generated by a Burdick Microtherm diathermy device, was used at an absorbed power = 1.6 W/cm². Experiments were run with bath temperature maintained at 37.5 C, in a bath cooled below 37.5 C, and without maintaining a constant temperature bath. In all cases, attenuation of the ventral root potential depended directly on temperature; as temperature increased, ventral root potential decreased, but always recovered to initial values as temperature stabilized to 37 C. Thus CNS function is altered by MW radiation, but only to the same extent as non-radiation heating. (10 references)

0485 EFFECTS OF MODULATED VHF FIELDS ON THE CENTRAL NERVOUS SYSTEM. (E.) Bawin, S. M. (Space Biol. Lab., Univ. California, Los Angeles), L. K. Kaczmarek, and W. R. Adey. *Ann. N. Y. Acad. Sci.* 247, 74-81, 1975.

The chick forebrain was chosen for an investigation of possible interactions between extracellular weak voltage gradients induced by the VHF radiation and ionic movement in cerebral tissue. The forebrain was used because it was previously shown to be highly sensitive to small perturbations of extracellular concentrations of Ca²⁺ and Mg²⁺. Ca²⁺ fluxes from irradiated brains were compared at various frequencies of amplitude modulation. Experiments were conducted in a specially adapted environmental chamber at field

intensities of 1-2 mW/cm². Five hundred neonatal chicks were decapitated; forebrains were dissected from the cranial cavities and incubated for 30 min in 1 ml physiologic medium and 0.2 ml saline containing 0.2 μ Ci of ⁴⁵Ca²⁺. The samples were exposed to irradiation with sinusoidal modulation at 0.5, 3, 6, 9, 11, 16, 20, 25, or 35 Hz. In each experiment 3 series of 10 samples were irradiated with VHF fields modulated at 3 different frequencies and radioactivity was measured. An additional series of 40 chicks was used to compare field effects on ⁴⁵Ca²⁺ efflux from brains poisoned after incubation with 10⁻⁴ M NaCN. Preliminary experiments were also run on skeletal muscle tissue. Unmodulated radiation and fields modulated at 0.5 and 3 Hz induced no significant change in the ⁴⁵Ca²⁺ efflux, but there was a progressive increase in the efflux from brains exposed at 6, 9, 11, and 16 Hz. These effects declined at higher frequencies and results at 35 Hz did not differ from controls. This indicated that the electrochemical equilibrium existing in cerebral tissues can be disrupted by small variations of surrounding ionic concentrations or local electric gradients. A small displacement of these ions could play an important role in propagation and amplification of local electrical events. The ⁴⁵Ca²⁺ fluxes were not influenced by CN⁻ poisoning, suggesting that the ionic exchanges observed were independent of ongoing metabolic processes. Preliminary test results on skeletal muscle showed that no significant changes in ⁴⁵Ca²⁺ efflux were triggered from striated muscle. The calcium ion movements under observation were critically related to specific components of the radiation. (30 references)

0486 SYNCHRONIZATION OF CORTICAL NEURONS BY A PULSED MICROWAVE FIELD AS EVIDENCED BY SPECTRAL ANALYSIS OF ELECTROCORTICOGRAMS FROM THE WHITE RAT. (E.) Servantie, B. (Mil. Hosp. Postgrad. Stud., Sainte Anne, Toulon-Naval, France), A. M. Servantie, and J. Etienne. *Ann. N. Y. Acad. Sci.*, 247, 82-86, 1975.

An attempt was made to demonstrate the action of MW fields on cerebral neurons. Albino Charles River rats (8 test, 10 controls) were irradiated for 10 days in free space conditions in an anechoic chamber. The rats were exposed to an average power density of 5 mW/cm² in a 3 GHz pulsed field (1 μ sec, 500-600 pps). After exposure occipital electrocorticograms were recorded and analyzed. For irradiated animals analysis yielded a line of the same frequency as that of the pulse repetition frequency of the radiation. The line is weak, but persists for several hr after termination of radiation. It is probably due to synchronization of cortical neurons by EM impulses. Two hypotheses are presented: (1) tissues of the animal head or cortex in which the electrical parameters are not linear change the impulses into electrical shocks which directly excite the neurons, or (2) the excitatory factor may be the magnetic component of the hyperfrequency field. (7 references)

0487 DO MICROWAVES ALTER NERVOUS SYSTEM STRUCTURE? (E.) Albert, E. N. (Dep. Anat., George Washington Univ., Washington, D. C.) and M.

DeSantis. *Ann. N. Y. Acad. Sci.* 247, 87-108, 1975.

Sixty adult Chinese hamsters were used to examine the CNS after irradiation with 2450 MHz EMR in an anechoic chamber. Exposure time was 30 min to 24 hr at 50 mW/cm² and 22 days at 25 mW/cm². Animals were sacrificed immediately after exposure or after a 1-2 wk recovery period. They were processed for light and electron microscopy, and tissues were stained for various tests. Animals exposed at 50 mW/cm² exhibited morphologic changes in the cytoplasm of certain neuron cell bodies. The cytoplasm of hypothalamic neurons was pale and displayed vacuolization and chromatolysis; no vacuoles were present in the cytoplasm or nuclei of glial cells. Cytopathologic phenomena were more numerous in animals sacrificed immediately after exposure as compared to those sacrificed 6-10 days after treatment. At 25 mW/cm² there was evidence of vacuolization and chromatolysis in hypothalamic neurons and vacuolization and frothy cytoplasm of neurons in the subthalamus. However, neurons adjacent to the thalamus and other CNS regions were unaltered relative to controls at both power densities. MWs had no effect on myelin; there was no evidence of gliosis, hemorrhage, or perivascular edema. These findings suggest that MWs at 25 and 50 mW/cm² and 2450 MHz consistently affect the hypothalamus and subthalamus. Changes appear to be chiefly cytoplasmic, although a decrease in the protein synthesis apparatus was also found. (14 references)

0488 EXPERIMENTAL MORPHOLOGIC AND ELECTROENCEPHALOGRAPHIC STUDIES OF MICROWAVE EFFECTS ON THE NERVOUS SYSTEM. (E.) Baranski, S. (Mil. Inst. Aviat. Med., Warsaw, Poland) and Z. Edelwejn. *Ann. N. Y. Acad. Sci.* 247, 109-116, 1975.

Chemical and experimental studies are reviewed in this paper. Personnel who had contact with MW sources were divided into 3 groups depending on the power densities to which they were exposed, and each group was subdivided according to the duration of exposure. Neurologic investigations were performed, including a detailed history, physical examination, and EEG. Subjective complaints of headache and sweating were frequent. Personnel exposed over long periods at high power density levels generally exhibited flat EEGs. Although no firm conclusions could be drawn, observations indicated that MW exposure may influence nervous system function. In experimental tests, rabbits received single or repeated exposure to 2950 MHz CW or PW (1200 Hz, 1 μ sec) MWs. Single irradiations were performed at 5-30 mW/cm²; repeated exposure was at 5 mW/cm², 2 hr/day for 3-4 mon. After irradiation, EEG recordings were made and histologic, histochemical and biochemical investigations were performed. Active acetylcholinesterase centers were determined and phosphorus and protein metabolism were followed with radioactive tracers. Long term exposure to pulsed MWs yielded: (1) a fall in incorporation of ³²P, especially in lipid and nucleic acid fractions of brain homogenate; and (2) desynchronized high-voltage records, resulting from chronic stimulation of brain stem structures. Long term CW and PW irradiation resulted in a loss of active acetylchol-

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inesterase centers and a decrease in radioactivity of different brain regions, particularly the midbrain. Pulsed MW effects were more pronounced than CW irradiation at the same mean power density and frequency. Investigations on effects of low level long term doses (5-7 mW/cm²) have shown that MWs primarily affect reticular formation of the brain. (16 references)

Part II. Effects on Special Senses

0489 POSSIBLE PHYSICAL SUBSTRATES FOR THE INTERACTION OF ELECTROMAGNETIC FIELDS WITH BIOLOGIC MEMBRANES. (E.) Grodsky, I. T. (Dep. Phys., Cleveland State Univ., Ohio). *Ann. N. Y. Acad. Sci.* 247, 117-124, 1975.

A physical, quantum-mechanical, theoretical model of several aspects of the structure of the greater membrane is summarized and its correlations with current experimental results and predictions of interactions of external EMF with the nervous system are considered. The model comprises the neuronal phospholipid sheet of the plasma membrane and constituents of intracellular spaces in brain tissue. The external EMFs considered consist of gradients far below those needed for direct intervention with action potentials or chemical transmitters at synaptic sites. Problems associated with rectification of modulated signals and transduction into brain tissue are also considered. The model is viable; its predictions and correlations suggest many experiments which need to be performed beyond measuring basic interaction energies. The model may be enhanced by being complicated in many different directions when more detailed experimental information on the structure of a greater membrane has been obtained. (14 references)

0490 INVESTIGATION OF SINGLE-EXPOSURE MICROWAVE OCULAR EFFECTS AT 3000 MHz. (E.) Appleton, B. (Walter Reed Army Med. Cent., Washington, D.C.), S. E. Hirsch, and P. V. K. Brown. *Ann. N.Y. Acad. Sci.* 247, 125-134, 1975.

To determine the ocular effects of a single exposure to MW radiation, the eyes of anesthetized albino rabbits were exposed to 10cm (3000 MHz) CW radiation with a focusing dish antenna. Power levels and durations were well above the cutaneous sensation level. Animals which received 100 or 200 mW/cm² for 15 or 30 min underwent no ocular changes during or immediately after exposure, nor did a 1 yr follow-up reveal lenticular changes. Animals subjected to 15 min exposures at 300, 400, or 500 mW/cm² exhibited acute ocular changes during exposure. These consisted of hyperemia of lids and conjunctiva, miosis, anterior chamber flare, engorgement of iris vessels, and periorbital cutaneous burns. The miosis and flare were present for approximately 24 hr. Most of the severe changes were noted with the higher power density exposures; subsequent examinations revealed no morphologic lenticular abnormalities. Animals which received 300 mW/cm² for 30 min died during exposure. In addition, 3 of 6 animals exposed at 500 mW/cm² for 15 min died, and the 3

survivors were greatly stressed. These results correlate well with previous work at 2450 MHz, in which a single MW exposure of > 15 min was required for cataract production at 300 mW/cm² and above. Single exposures at 200 mW/cm² for 30 min were not sufficient to cause cataracts. (29 references)

0491 SCREENING FOR CATARACTS AMONG VETERAN RADAR REPAIR AND MAINTENANCE TECHNICIANS. (E.) McAfee, R. D. (VA Hosp., New Orleans, La.), L. L. Cazenavette, and M. G. Holland. *Ann. N.Y. Acad. Sci.* 247, 135-141, 1975.

A pilot study was initiated on a discrete population of veterans, such as radar repairmen, to see if lens changes may have occurred after discharge from the Armed Services. A simple cataract viewer was used that permitted an intelligent operator to examine his own eyes after proper instructions. The shadowgraph viewer was a low-voltage transformer in a small electrically insulated box. It contained a focused lamp which illuminated a shiny aluminum ball housed in a cylindrical viewer containing a peephole. Slit-lamp biomicroscopic examination confirmed the accuracy of drawings of entopic phenomena done by the veterans. The research group will expand the study to include individuals who had specific tasks involving combined MW and possibly ionizing radiation, those who repaired high powered communications equipment that does not produce MW radiation but may produce ionizing radiation, those who were exposed to MW radiation in the absence of possible ionizing radiation, and controls exposed to neither radiation. The survey should help clarify whether alleged latent human MW cataract exists. (7 references)

0492 USE OF A DIELECTRIC LENS FOR EXPERIMENTAL MICROWAVE IRRADIATION OF THE EYE. (E.) Carpenter, R. L. (HEW, Bur. Radiol. Health, Winchester, Mass.), G. J. Hagan and E. S. Ferri. *Ann. N.Y. Acad. Sci.* 247, 142-154, 1975.

Whole-body exposure of experimental animals to far-zone field MW radiation results in resonant heating which may cause death from hyperthermia. An attempt was made to resolve this problem by placing a dielectric lens in the far zone and concentrating radiation on the eye positioned a short distance behind it. Comparison of the MW power concentrated by a constant-K lens and a solid polyethylene lens showed that the former was superior in that radiation (2.45 and 10 GHz) was increased 7- to 13-fold in the eye relative to the rest of the body. During 30 min exposures of New Zealand White rabbits at 2.45 and 10 GHz, body temperature increased 6.7 and 4.3 C, resp., without the constant-K lens, compared with 1.2 and 0.5 C with the lens. Intraocular temperature at these frequencies rose 9 and 14.8 C without the lens versus 5.2 and 7.1 C when the lens was used. The greater rise in body temperature at 2.45 GHz suggests that radiation penetrates more deeply at this frequency and that energy is therefore absorbed by a greater volume of tissue. The

higher intraocular temperature induced by 10 GHz may reflect weaker penetration and absorption by the more superficial layers of tissue, including the highly vascular ciliary body and iris of the eye. Results for the 2.45 GHz frequency showed that with the constant-K lens, the animal had little effect on the MW power except when measurements were made 5-6 cm behind the lens. (15 references)

0493 THE OCULAR EFFECTS OF MICROWAVES ON HYPOTHERMIC RABBITS: A STUDY OF MICRO-WAVE CATARACTOGENIC MECHANISMS. (E.) Kramar, P. O. (Dep. Ophthalmol., Univ. Washington Sch. Med., Seattle), A. F. Emery, A. W. Guy, and J. C. Lin. *Ann. N.Y. Acad. Sci.* 247, 155-165, 1975.

Cataract production following near-zone 2.45 GHz radiation was studied in 8-month-old New Zealand albino rabbits in which the retrolental temperature was kept below 41 C by means of general hypothermia. Initially, rectal and retrolental temperatures were measured during 30, 20, and 15 min exposures of hypothermic rabbits to absorbed power densities of 184, 276, and 368 W/kg, resp., and incident power densities of 200, 300, and 400 mW/cm². Results showed the necessity of establishing a general body temperature to prevent elevations above 41 C. This temperature (25-31 C) was distinct for each power level and decreased with an increase in incident power density. Under conditions of controlled hypothermia, animals exposed to 2.45 GHz at 5 cm from the corneal surface did not develop cataracts. Although slight tearing and pupillary constriction were observed immediately after irradiation, these effects disappeared on day 2. The lenses of all animals remained clear throughout a 2-3 month observation period. Measured intraocular temperature distributions in irradiated, hypothermic rabbits (rectal temperature 29.6 C, ambient air, 24.3 C, ice bath, 22.9 C) showed good agreement with values predicted by a computer model. The isothermic pattern was similar to that for normothermic animals, except for the reduced temperature levels. This study indicates that radiation-induced temperature elevations are essential for the cataractogenic effects of MWs. (8 references)

0494 ULTRASTRUCTURAL CHANGES IN THE RABBIT LENS INDUCED BY MICROWAVE RADIATION. (E.) Williams, R. J. (Duke Univ. Eye Cent., Durham, N.C.), A. McKee and E. D. Finch. *Ann. N.Y. Acad. Sci.* 247, 166-174, 1975.

The effects of 2450 MHz CW MW energy on the ocular lens were studied in male New Zealand white rabbits divided into two groups of 6 animals each. The first group was irradiated with 250 mW/cm² for 20 min/day, 5 days/wk, for a total of 6 wk; the second group was exposed to 165 mW/cm² for 20 min twice daily (2 hr interval), 5 days/wk, for a total of 36 exposures. When sacrificed 2 wk after the last exposure, all animals in the first group had lens

opacities detectable by slit-lamp examination. In severely damaged lenses, initial biomicroscopic changes appeared during the third wk and consisted of vacuolization and haziness of the posterior subcapsular cortex; by the sixth wk, most of the posterior subcapsular cortex was opaque. At time of sacrifice, the opacity had discrete margins and resembled a disk of matted cotton centered at the posterior pole just under the capsule. Under the electron microscope, cells of the immediate subcapsular region of the lens were markedly deformed; cells between this region and the interior of the lens were variably affected. Reduplication and degeneration of the membrane was observed in some cells along with large cystoid spaces (intra- and extracellular) subjacent to the capsule at the posterior pole. Although lenses of all animals in the second group appeared normal by slit-lamp examination, electron microscopy showed substantial morphological alterations. Fibers of the posterior subcapsular cortex were generally enlarged, some containing large craters, and large intracellular clefts were present throughout the posterior subcapsular region. (5 references)

0495 ASCORBIC ACID CHANGES IN CULTURED RABBIT LENSES AFTER MICROWAVE IRRADIATION. (E.) Weiter, J. J. (Environ. Biosci. Dep., Naval Med. Res. Inst., Bethesda, Md.), E. D. Finch, W. Schultz, and V. Frattali. *Ann. N.Y. Acad. Sci.* 247, 175-181, 1975.

A study was conducted to evaluate nonthermal effects and radiation modulation of MWs on whole lens tissue cultures using changes in ascorbic acid concentration as an indicator of lens damage. The decrease in ascorbic acid concentration is the earliest detectable biochemical indicator of lens damage. The lenses of New Zealand white rabbits were removed aseptically, transferred to a culture medium (rabbit serum, Earle's modified salt base, penicillin, and streptomycin), and incubated at 37 C for 48 hr prior to irradiation. Effects of pulsed vs CW S-band radiation were compared, as well as exposure of control lens in matched time-temperature environments without irradiation to that produced by exposure to MWs. All effects produced a decrease in ascorbic acid concentration in the lenses. There was direct correlation between decreased concentration and MW power with no apparent threshold of activity. No differences were found between irradiated and control lenses subjected to identical time-temperature conditions. At any given average power density, time-temperature variation was independent of modulation; equivalent decreases in ascorbic acid concentrations were produced, indicating a purely thermal phenomenon. If the effect had been nonthermal, peak power should have been a significant factor. Therefore, MW lens damage is a thermal phenomenon; however, no critical threshold temperature was found. If repetitive insults occur before sufficient time has elapsed for repair, long-term exposure to lower power MWs might lead to irreversible morphologic damage. (15 references)

0496 DETECTION OF WEAK ELECTROMAGNETIC RADIATION BY THE MAMMALIAN VESTIBULOCOCHLEAR APPARATUS. (E.) Lebovitz, R. M. (Univ. Texas Southwestern Med. Sch., Dallas). *Ann. N.Y. Acad. Sci.* 247, 182-193, 1975.

Slow caloric or thermal stimulation of the vestibular apparatus is examined as a mechanism for the auditory perception of MW radiation at levels below those associated with acute thermal damage (10-30 mW/cm² or less in humans). The vestibular hypothesis implies that the auditory effect of MW radiation should be strongly dependent on orientation of the head relative to the vertical axis but only weakly dependent on orientation relative to the source under nonresonance conditions. Caloric vestibular effects of MWs could give rise to sensations of angular acceleration mediated via the semicircular canals and perhaps to ill-defined vibratory or auditory sensations mediated via saccule and utricle by similar thermal mechanisms. The hypothesis assumes several potential mechanisms for a behavioral cue value in MW radiation at low levels of incident power density, cues that can be derived only from basic thermal mechanisms plus the well-documented sensitivity of inner ear structures. If sharp resonance absorption can be demonstrated, MW vestibular interaction offers the possibility of developing new clinical diagnostic tools (e.g., MW based tests of vestibular function). Other mechanisms are reviewed whereby auditory and mixed audiovestibular effects might derive from weak, but modulation-sensitive, electromechanical effects of incident MW radiation, i.e., radiation pressure and dielectrophoresis. It is hypothesized that phasic displacement of the tympanic membrane should occur coincidentally with pulse-modulated MW radiation. (21 references)

0497 MICROWAVE-INDUCED ACOUSTIC EFFECTS IN MAMMALIAN AUDITORY SYSTEMS AND PHYSICAL MATERIALS. (E.) Guy, A. W. (Univ. Washington Sch. Med., Seattle), C. K. Chou, J. C. Lin, and D. Christensen. *Ann. N.Y. Acad. Sci.* 247, 194-218, 1975.

The threshold of the acoustic effect of pulsed MWs in man and animals was studied as a function of pulse power or energy, pulse shape, and carrier frequency. In addition, the locus of action of the effect was investigated. The studies involved establishment of incident field and modulation characteristics at the threshold for auditory sensation in humans; comparison of activity evoked in four successive levels of the auditory nervous system in the cat due to incident acoustic and MW pulses; assessment of the deactivation of the cochlea, the first known stage of transduction for acoustic stimuli on the potentials evoked by both forms of pulsed energy; quantitation of the transduction of MW pulse energy to acoustic energy in MW-absorbing materials by optical interferometry; and demonstration that the MW auditory phenomenon is consistent with direct conversion of EM energy in tissues. Two

human subjects were exposed to 2450 MHz (3 pulses/sec, pulse width 1-32 μ sec, background noise 45 dB). Cats were exposed to 2450 MHz (1 pulse/sec, background noise 64 dB) and 918 MHz (1 pulse/sec, background noise 64 dB). In both humans and cats, the threshold for MW pulse-evoked auditory sensations was related to the incident energy/pulse. With pulses less than 30 μ sec wide, values were approximately 20 μ J/cm² for cats and 40 μ J/cm² for humans. These values correspond to a peak power absorbed density of 10-16 mJ/kg in the cat head and 16 mJ/kg in the human head. As background noise increased, the threshold for evoked responses in the medial geniculate nucleus of the cat remained stable for pulsed MW stimuli but increased for acoustic stimuli. Cochlear destruction resulted in total loss of all evoked potentials due to MW and acoustic stimuli, indicating that the MW auditory effect is exerted in the same manner as conventional acoustic effects. The most likely mechanism of EM field interaction is apparently conversion of EM energy to acoustic energy due to thermal expansion, as determined by predicted and measured values of thermal forces in liquid and solid materials exposed to MW pulses. That sounds are mediated by pulse energy levels sufficient to raise tissue temperature only 5×10^{-6} C indicates that care must be exercised in classifying an effect as thermal or nonthermal on the basis of the level of temperature increase. (20 references)

0498 ACTION OF CORTI'S ORGAN AND THE COCHLEA: A NEW THEORY. (E.) Malcolm, J. E. (Roy. Air Force, Cent. Med. Establish., London, England). *Ann. N. Y. Acad. Sci.* 247, 219-231, 1975.

A model simulating the action of Corti's organ and the cochlea is described. It considers the labyrinth as a whole, based on a monoclinic crystal which is birefringent, rotates plane-polarized light, and is optically active. It is not necessarily at variance with direct observation although these observations may be interpreted differently. Increased cochlear electric potential, which represents stored energy, is associated with a mechanical translation of the basilar membrane and angular separation of Corti's rods and is effected by 'pumping' by the endolymphatic sac and the muscles that act on the auditory ossicles. The semicircular canals function as valves; the utricular and saccular macules form holograms and reflect the energy into the cochlear duct. Incoming acoustic waves excite dipole resonance and stimulate emission of a fraction of the stored energy; further amplification is effected by the hair cells, which, together with the tectorial membrane, behave like a transistor. These suggest a new theory of static balance and the action of Corti's organ: the labyrinth functions as a traveling wave maser of which the cochlea is the slow wave structure. Cochlear geometry itself effects resolution of incoming pitch. Corti's organ corresponds to the melatopes of the crystal, and the inter-rod angle is critical for any particular frequency, since it is related to the dispersion of the optic axes. (8 references)

Part III. Biochemical and Biophysical Effects

0499 MICROWAVE EFFECTS ON THE BLOOD-FORMING SYSTEM WITH PARTICULAR REFERENCE TO THE LYMPHOCYTE. (E.) Czernski, P. (Dep. Human Genet., Natl. Res. Inst. Mother Child, Warsaw, Poland). *Ann. N. Y. Acad. Sci.* 247, 232-242, 1975.

Three sets of experiments were performed to study the responses of blood and blood-forming systems to low levels of MW radiation. In the first, male CWF mice were used to determine the influence of MWs on the response of immunocompetent lymphocytes. The mice were irradiated for 2 hr daily with 2950 MHz pulsed MWs in far-field conditions at 0.5 mW/cm² mean power density. One hundred mice were exposed for 6 wk and 100 for 12 wk, 6 days/wk. After termination of exposure, the animals were immunized and 5 mice from each group were sacrificed on days 4, 6, 8, 12, and 20. Lymphoblast and plasmocyte percentages were determined, the immune response was measured, and serum hemagglutinins were estimated. Significant differences in immune response from controls were obtained in mice irradiated for 6 wk, but not in those exposed for 12 wk, indicating that the animals adapt to the MWs after a period of response. In the 2nd experiment, 12 rabbits were irradiated (2950 MHz, pulsed 1200 Hz, 1 μ sec) 2 hr/day for 6 mon at 5 mW/cm². Peripheral blood was obtained each mon and lymphocyte cultures were counted. After an initial period in which the number of cells undergoing spontaneous lymphoblastoid transformation increased, the values returned to baseline with a 2nd increase one mon after irradiation terminated. In a 3rd series of experiments human lymphocyte suspensions were treated with 2950 MHz MWs for various periods at several power densities and the percentage of lymphoblastoid cells was determined. Preliminary results are poorly reproducible but suggest that *in vitro* exposure may induce lymphoblastoid transformation. These experiments indicate that studies of the response of the hematopoietic system to MWs may reveal subtle effects at low power densities. (18 references)

0500 THE EFFECT OF ELECTROMAGNETIC RADIATION ON THE HEMATOPOIETIC STEM CELLS OF MICE. (E.) Rotkovská, D. (Inst. Biophys., Czechoslovak Acad. Sci., Brno) and A. Vacek. *Ann. N. Y. Acad. Sci.* 247, 243-250, 1975.

The effect of whole body MW irradiation on hematopoietic cell populations and a comparison with the influence of external heat has been studied. Two-month-old female C57B1/10 mice were exposed to 100 mW/cm² 2450 MHz radiation. Groups of 5 mice were irradiated for 5 min; rectal temperatures were measured before and after irradiation. Leukocyte and erythrocyte counts in peripheral blood and the number of cells in the femur and spleen were estimated. ⁵⁹Fe was administered into the spleen and bone marrow and followed until 20 days after irradiation or heating. The mice were sacrificed, spleens and femurs removed, and activities of individual organs were measured. Two waves of increase in leukocyte count occurred after irradiation: the first lasted

until day 4 and the 2nd reached a maximum on day 6, returning to the initial level on day 7. Exposure to heat resulted in a rise in leukocyte count which persisted to day 7 with a maximum on day 4. Erythrocyte count was unaltered by irradiation and heat. ⁵⁹Fe incorporation decreased to 78% within 24 hr of irradiation, then increased to 250% on day 14. After heat exposure, ⁵⁹Fe incorporation increased initially, decreased during the 2nd and 3rd day, and returned to normal. Cell count decreased up to 72 hr after irradiation, then increased during days 4-7 in the spleen. No significant change was noted in the femur. The different effects of MWs and externally applied heat on hematopoietic stem cells suggests that alterations caused by high-intensity MW radiation are not related only to increased internal temperature. (9 references)

0501 THE EFFECT OF MICROWAVES (2450 MHz) ON ISOLATED RAT LIVER MITOCHONDRIA. (E.) Elder, J. A. (Exp. Biol. Lab., Natl. Environ. Res. Cent., Research Triangle Park, N.C.) and J. S. Ali. *Ann. N.Y. Acad. Sci.* 247, 251-262, 1975.

An *in vitro* study on the effects of 2450 MHz radiation on rat liver mitochondria exposed to power densities of 10 and 50 mW/cm² was performed. Temperature was maintained at < 4 C. Long-Evans rats fasted overnight. Liver mitochondria were isolated in 0.25 M sucrose and resuspended in sucrose to 50 mg/ml. Two ml of the suspension in a petri dish were placed in the exposure chamber at 0 C. At 0.5 hr intervals over a 2.5 hr period an aliquot of sample was removed and oxygen uptake measured. Aliquots of control sample kept at 0 C were measured alternatively. The experiment was repeated 3 times at each exposure. Oxygen consumption was measured at 25 C. Results showed no differences in respiratory control of mitochondria at either exposure level as compared to control. ADP/O ratios were in good agreement with the normal values, and there was no alteration in response of mitochondria to calcium ions. A statistical analysis ($p < 0.05$) found no differences between slopes of irradiated and control samples. Thus, no effects of MW radiation were found on the molecular processes of substrate oxidation, electron transport, oxidative phosphorylation and calcium transport during 3.5 hr exposures to 10 and 50 mW/cm² power densities. (19 references)

0502 EFFECT OF MICROWAVES ON CELL FUNCTION AND VIRUS REPLICATION IN CELL CULTURES IRRADIATED IN VITRO. (E.) Szmigielski, S. (Inst. Aviat. Med. Dep. Med. Microbiol., Univ. Med. Sch., Warsaw, Poland), M. Luczak, and M. Wiranowska. *Ann. N.Y. Acad. Sci.* 247, 263-274, 1975.

Morphological and cytochemical studies were performed on WISH cells 1, 24, and 48 hr after *in vitro* radiation with 3 GHz EM waves. Cultures infected with parainfluenza 3 virus (10^6 TCID₅₀/ml) 1 or 2 hr after irradiation, or irradiated with MWs 2, 8, or 16 hr after virus infection, were examined for morphological changes and virus multiplication at

48 hr postinfection. The reduction rate of nitro blue tetrazolium in WISH cells 1 hr after irradiation at 20 mW/cm² was markedly decreased. Only 10-15% of the cells showed large granules and/or formazan deposits and diffuse staining, compared with 50-70% of control cells. The percentage of cells with succinic dehydrogenase activity declined markedly in irradiated cultures. By 24 hr postirradiation, cell function had partially returned to normal. The reduction rate of nitro blue tetrazolium increased in cells 24 hr after irradiation at 5 mW/cm² and returned to normal by 48 hr. At both 20 and 5 mW/cm², the percentage of nigrosine-stained cells was comparable to control values. Virus infection was accompanied by an increase in the number of nigrosine-stained cells, a decline in nitro blue tetrazolium, and an increase in succinic dehydrogenase activity. Irradiation at 5 mW/cm², but not at 20 mW/cm², stimulated virus multiplication regardless of whether exposure occurred before or after virus infection. This increase in virus multiplication was accompanied by a significantly higher reduction of nitro blue tetrazolium, particularly in cells infected before irradiation. Stimulation of oxidative metabolism by this radiation dose may be the cause of increased virus multiplication. Since WISH cells react differently to 5 and 20 mW/cm² power densities, quantitation of the energy absorbed is a problem. Nevertheless, continuous cell-line monolayers *in vitro* are an attractive model for studying the effects of MW radiation on cell metabolism. (14 references)

0503 EFFECT OF 10-CM (3 GHz) ELECTROMAGNETIC RADIATION (MICROWAVES) ON GRANULOCYTES IN VITRO. (E.) Szmigielski, S. (Inst. Aviat. Med., Warsaw, Poland). *Ann. N. Y. Acad. Sci.* 247, 275-281, 1975.

The effect of low level (1 mW/cm²) MW fields on injury to the cell membrane and potassium efflux from erythrocytes after *in vitro* irradiation was determined. Pre-treated rabbit granulocytes were isolated from the peritoneal cavity and suspended in heparinized saline. The percentage of granulocytes was measured and suspensions containing at least 90% mature granulocytes were exposed to 3 GHz EM waves (1 or 5 mW/cm²) under far field conditions for 15, 30, or 60 min. The percentage of dead cells was determined, phase-constant microscopy of living cells was performed, acid and alkaline phosphatase and lysozyme activities were measured, and formazan concentration was determined in nitro blue tetrazolium solution and pyridine. There was an increased percentage of dead cells only in suspensions exposed to 5 mW/cm² radiation for 30 or 60 min. Under phase-constant microscopy many vacuoles stained with neutral red were visible in cells exposed to 5 mW/cm² for 30 or 60 min. Acid phosphatase and lysozyme were liberated from granulocytes at either power density and were dependent on both time and dose. After irradiation at 5 mW/cm² the number of nitro blue tetrazolium reducing granulocytes was elevated at 15 and 30 min followed by a rapid decline at 60 min exposure. These observations suggest that specific cellular injury, which is dose and time de-

pendent, is produced *in vitro* by low level radiation and that MW radiation disturbs cellular membranes. The stimulation of energetic metabolism seems to be a reversible disturbance whereas the decline in nitro blue tetrazolium reduction and liberation of lysosomal enzymes are symptoms of irreversible injury. (21 references)

0504 A COMPARISON OF THERMAL AND RADIO-FREQUENCY EXPOSURE EFFECTS ON TRACE METAL CONTENT OF BLOOD PLASMA AND LIVER CELL FRACTIONS OF RODENTS. (E.) Rupp, T. (Radiobiol. Div., U. S. Air Force Sch. Aerosp. Med., Brooks Air Force Base, Tex.), J. Montet, and J. W. Frazer. *Ann. N.Y. Acad. Sci.* 247, 282-291, 1975.

Present MW exposure standards in the U. S. are primarily based on an estimation of the thermal insult involved; to determine the extent of damage, the nature of the biochemical changes induced is important. Experiments were run to determine changes in plasma metal content and to compare changes induced by MW exposure to those brought about by thermal exposure. Male Sprague-Dawley rats were exposed for 45 minutes in a hot air drying oven to external temperatures sufficient to raise body temperature to 40, 42, and 45 C. The animals were anesthetized, blood was withdrawn and the liver was excised, weighed, homogenized and centrifuged. Various aliquots of the liver and blood plasma were tested for Zn, Fe, Cu, Ca, and Mg. Experimental animals were exposed to RF radiation (H-field ~ 77 A/m, E-field ~ 30 kV/m) in the USAFSAM HF band exposure system; core temperatures were matched with those produced thermally and the same blood and liver tests were run. Elevation in plasma iron content was found after exposure, with half the rise coming from loss by the liver. A small increase in globulin was noted after RF exposure but not after thermal exposure. The plasma content of Mg, Ca, and Zn did not change appreciably although total and heavy particle content of Mg decreased appreciably after RF exposure. The alterations noted seemed to take place only in extreme fields with a large thermal component. Thus, some thermally produced changes in divalent metal distribution in rat liver can be duplicated by application of high-intensity RF fields. (12 references)

0505 EFFECTS OF ELECTROMAGNETIC FIELDS ON MICROSOMAL ATPase AND MITOCHONDRIAL OXIDATIVE PHOSPHORYLATION. (E.) Straub, K. D. (VA Hosp., Little Rock, Ark.) and P. Carver. *Ann. N. Y. Acad. Sci.* 247, 292-300, 1975.

Experiments were performed to determine the effects of electric and EM fields on Na-K ATPase from guinea pig brain, oxidative phosphorylation in rat liver mitochondria, and frog skin ion transport. Membrane-bound Na-K ATPase was prepared from guinea pig brain and assayed by measuring the release of inorganic phosphate from ATP. Mitochondria were assayed at 22 C in a Clark oxygen electrode and ADP/O ratios

were calculated. Potential difference and short circuit current were measured on the ventral skins of grass frogs. CW MW power (maximum 2-5 mW/cm²) was generated by backward wave oscillators of appropriate frequency. Frog skin was very sensitive to low frequency currents; after 10 sec exposure to 20 Hz at a current density of 400 μ A/cm², skin potential increased 200% while short circuit current increased 35%. Three effects were noted: at low density there is an increase in potential difference, with little change in the short circuit current; this signifies a decrease in passive ion flux without change in active transport. At higher current density, increases which occur in both potential difference and short circuit current could be due to active ion transport and/or decreased passive ion movement. Very high densities cause irreversible damage to membrane structures with a decrease in ion transport and increase in passive permeability to ions. No effects were seen on microsomal preparations from guinea pig brain for either Na-K ATPase or ADP/O ratios. No effects were noted on rat liver mitochondria exposed in low frequency ac fields or at MW frequencies. For MW exposure, the incident power density may be less than that calculated due to experimental conditions incurred. However, there was no evidence of MW effects at equivalent power levels = 1-2 mW/cm². (8 references))

0506 EFFECTS OF MICROWAVE RADIATION ON ENZYMES.
(E.) Yeagers, E. K. (Biol. Dep., Georgia Inst. Technol., Atlanta), J. B. Langley, A. P. Sheppard, and G. K. Huddleston. *Ann. N.Y. Acad. Sci.* 247, 301-304, 1975.

Enzymes have been chosen as the test subject of experiments to investigate their sensitivity to MW energy and to apply these effects to living organisms as a whole. Most enzymes are characterized by a high sensitivity to heat so tests were run to compare the results of conductive and convective heating with the results of MW absorption and its resultant heating effect. Any differences should be due to effects which are uniquely those of MW radiation. A 2450 MHz Litton Industries magnetron was used as the source of MW energy and the power level was controlled by a high power attenuator. Lysozyme and trypsin (10⁻⁶ M solutions) were heated at MW levels of 50 to 300 W until a specific temperature between 30 and 95 C was reached. The desired temperature was maintained for 1.5 hr then the samples were permitted to cool to room temperature and assayed. An unheated control was also assayed. The curves for the MW and conventionally heated samples were essentially parallel with no discernable differences in enzyme performance after 50 independent measurements. Thus, no differences in enzyme activity were observed as a function of the heating methods. (No references)

0507 ACUTE STAPHYLOCOCCAL INFECTIONS IN RABBITS IRRADIATED WITH 3 GHz MICROWAVES.
(E.) Szmigieliski, S. (Inst. Aviat. Med. Natl. Inst. Hyg., Warsaw, Poland), J. Jeljaszewicz, and M. Wir-

anowska. *Ann. N.Y. Acad. Sci.* 247, 305-311, 1975.

Experiments were performed on 10 adult rabbits to examine granulopoietic reaction after long-term exposure to nonthermal MW radiation concurrent with acute staphylococcal infection. Five rabbits were exposed for 6 wk and 5 for 3 mo in an anechoic chamber to 3 GHz EM waves in far field conditions. Irradiation was at 3 mW/cm² for 6 hr/day. After exposure, animals were infected i.v. with virulent *M. pyogenes*, variety. Before and 4, 6, 10, and 14 days post infection functional tests of granulopoiesis were performed on the 10 test rabbits and 5 controls. In controls the number of leukocytes and granulocytes in peripheral blood increased during the entire observation period; a higher percentage of young granulocytic cell forms was found in bone marrow 10-14 days after infection. Irradiated animals differed from controls in behavior, granulopoietic reaction differed markedly, and the clinical course of the disease was more serious. Rabbits after 6 wk exposure displayed stronger leukocytosis and granulocytosis 4 and 6 days after infection, followed by a dramatic drop below normal values 10 and 14 days after infection. There was also a decline in the bone marrow reserve pool and reduced lysozyme activity during the entire observation period. Animals exposed for 3 mon displayed much lower leukocytosis and granulocytosis after infection as compared to controls despite similar pre-infection values. There was a relative increase in percentage of younger granulocytic cell forms. Thus prolonged exposure to low levels of MWs resulted in decreased production of mature granulocytes, but a proper level of granulocyte numbers was maintained in the peripheral blood and impaired reactivity of the system occurred only after action of stimulatory agents. (21 references)

0508 DISCUSSION PAPER: IRRADIATION OF BOVINE SERUM ALBUMIN WITH A CROSSED-BEAM EXPOSURE-DETECTION SYSTEM. (E.) Allis, J. W. (Exp. Biol. Lab., EPA, Research Triangle Park, N.C.). *Ann. N.Y. Acad. Sci.* 247, 312-322, 1975.

Bovine serum albumin (BSA) was used to determine whether S-band MW radiation has a direct interaction with proteins and whether there is a dependence on protein flexibility. By means of UV difference spectroscopy, changes in the environment of UV-absorbing amino acids (tryptophan, tyrosine, and phenylalanine) were studied as a function of molecular flexibility during MW perturbation. Difference spectra of BSA were run with 2.45 GHz radiation (absorbed dose, 30, 70, and 100 mW/g) for deionized protein and defatted protein. Difference spectra were also run with 1.70 GHz radiation (37 and 54 mW/g) for deionized protein only. Measurements were made at wavelengths from 300-240 nm (330-240 nm for defatted BSA), five pH values (4.5, 3.7, 3.0, 2.5, and 2.0) and sample temperatures of 25-26 to 34-35 C. Whether obtained just after irradiation was begun or at 30 min all difference spectra yielded uniform results: no differences were noted in samples irradiated by MWs at either frequency. In addition, there were no differences between irradiated and un-

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irradiated samples. As a further control, acrylamide gel electrophoresis experiments were done on BSA from the irradiated sample, BSA from the reference chamber of the spectrophotometer, totally untreated BSA, and BSA heated to 75 C for 15 min. No difference was observed except in the protein heated to 75 C, which showed marked deterioration. It is concluded that protein flexibility is not a sensitive parameter in the S-band region of the MW frequency spectrum; furthermore the relaxation of bound water at the surface of proteins excited by these frequencies is not significant for protein structure. (12 references)

0509 DISCUSSION PAPER: RAMAN SPECTROSCOPY OF MOLECULAR SPECIES DURING EXPOSURE TO 100-MHZ RADIO-FREQUENCY FIELDS. (E.) Klainer, S. M. (Res. Eng. Div., Block Eng., Inc., Cambridge, Mass.), and J. W. Frazer. *Ann. N.Y. Acad. Sci.* 247, 323-326, 1975.

The use of lasers as light sources for Raman spectrometers allows direct observation of the effects of applied fields on polar molecules in aqueous solution. These molecules can orient themselves over a frequency range that depends on charge distribution, solvent viscosity, and molecular weight. Ten percent solutions of glycine, ATP, *E. coli* tRNA, and electrophoretically homogeneous chymotrypsin were prepared. An argon laser was used and measurements were made at 0.4880 μ m. Constant temperature was maintained. When RF fields were applied, no perturbations of glycine or ATP spectra were found. *E. coli* tRNA lost several peaks associated with intramolecular hydrogen bonding after 1 hr of exposure and power feed of 8 W. In chymotrypsin the progressive loss of prominent peaks at input power of 3 W and 4 W was noted in the vibrational spectra of the molecular backbone. At 5 W the solution became very turbid. Alterations in the Raman spectra may reveal information usually found in dielectric dispersion spectra and may show effects of applied fields on the tertiary structure of large molecules. (5 references)

Part IV. Effects on Genetics and Development

0510 GENETIC CONTINUITY AND METABOLIC REGULATION AS SEEN BY THE EFFECTS OF VARIOUS MICROWAVE AND BLACK LIGHT FREQUENCIES ON THESE PHENOMENA. (E.) Webb, S. J. (Dep. Bacteriol., Univ. Saskatchewan, Saskatoon, Canada). *Ann. N.Y. Acad. Sci.* 247, 327-351, 1975.

Experiments were performed to determine the time at which the synthesis and activity of β -galactosidase occur in *Escherichia coli* B cells, the effects of nutrition on mutation by 320-410 nm light, and the action of MWs on metabolic events in bacterial and mammalian cells. The enzyme appeared in cells after 10 min incubation in amino acid-lactose medium and reached its maximum level 10 min later. 14 C-carbon dioxide did not appear before 40 min, approximately 20 min before the cells underwent their first cell division. In cells induced in a succinate-NH₄Cl-

lactose medium, the enzyme did not appear until after 155 min of incubation, and 14 C-carbon dioxide did not appear before 155 min, approximately 10 min before the first cell division. After the first and second divisions, only 50 and 75-80% of the daughter cells, resp., contained the new metabolic systems conducive to new nutritional environments. Only when 14 C-lactose respiration began (25-40 min after the appearance of β -galactosidase) were cells able to proliferate on NH₄⁺ salts-lactose agar. In addition, glucose acted as a competitive inhibitor only when added to lactose induction medium prior to enzyme appearance. Study of mutations induced by 320-410 nm light in synchronized lag phase cultures of *E. coli* demonstrated that an absorbing chromatophore, present in the membrane respiratory chain, traverses the DNA and sequentially contacts each gene at a definite time in the life of a cell. The time lapse between successive contacts depends on nutrition, particularly carbon, and is between 30-45 min. Data for bacterial cells exposed to a field density of 10-50 mW/cm² showed that two sets of frequencies affected protein and DNA synthesis of cells in glucose-amino acid medium. In one set the frequencies are separated by integral multiples of 7 GHz; in the other, by 5 GHz. Both the frequencies absorbed and their separation are controlled by the nutrition supplied. All normal mammalian cells tested absorbed given MW frequencies between 50-90 GHz which influenced the rates of protein and DNA synthesis and which formed two series separated by 2.0 and 2.5 GHz, resp. The frequencies absorbed by tumor cells appeared to form 2, and perhaps 3, series separated by 1.0-2.0, 2.3, and 2.7 GHz, resp. As a given cell strain changed from highly tumorigenic to nontumorigenic, the strength of attenuation in the 2.3 and 2.7 GHz series of frequencies absorbed decreased and that of frequencies in the 2.5 GHz series occurred or increased. In an effort to explain these observations, a new concept of cell metabolism and its genetic control is presented in detail. (50 references)

0511 EFFECTS OF NONIONIZING ELECTROMAGNETIC RADIATION ON SINGLE-CELL BIOLOGIC SYSTEMS. (E.) Blackman, C. F. (Exp. Biol. Lab., Nat. Environ. Res. Cent., Research Triangle Park, N.C.), S. G. Benane, C. M. Weil, and J. S. Ali. *Ann. N.Y. Acad. Sci.* 247, 352-366, 1975.

The effect of MW irradiation on growth of two strains of *E. coli* was investigated with two environmental control chambers. A large chamber provided temperature regulation to \pm 0.5 C and was used for free-field CW irradiations at 1.70 or 2.45 GHz. A small chamber providing temperature regulation to \pm 0.1 C was used for far- and near-field irradiations at 68-74 GHz. Exposure of strain Cs, grown in tryptone broth at 32 C, to 2.45 GHz (power density 0.005, 0.5, 5.0, 50 mW/cm²) did not inhibit cell growth, as shown by comparison of the ratios of the number of cell doublings for MW treated samples with those for control samples. Slight (0.2-0.3 C) radiative heat losses were found to affect *E. coli* growth. No MW-induced inhibition of log or lag phase cells re-

sulted from irradiation in tryptone broth at 25 C. Similarly, in glucose-minimal salts medium, there was no inhibition of log phase cells at 32 or 25 C or of lag phase cells at 32 C. Experiments with ϕ X 174 virus and strain Cs indicated no MW induced inhibition of virus growth. Strain WWU cells (log phase, grown on glucose B1, irradiated at 30 C) were exposed over the range 1.70-74 GHz. The irradiated samples grew sufficiently beyond one cell doubling to suggest no radiation induced inhibition. Results for cell growth at 35 C after carbon and nitrogen source changes also failed to demonstrate growth inhibition. In all experiments, the only obvious effect of MWs was enhanced cell growth, which can be attributed solely to slight temperature rises in the test system. (20 references)

0512 EFFECTS OF ELECTROMAGNETIC RADIATION ON IMPLANTATION AND INTRAUTERINE DEVELOPMENT OF THE RAT. (E.) Dietzel, F. (Dep. Nucl. Med., Justus Liebig-Univ. of Giessen, Germany). *Ann. N. Y. Acad. Sci.* 247, 367-376, 1975.

The effects of HF treatment of the abdomen on the intrauterine development of 7800 embryos of 749 pregnant rats were evaluated. The rats were treated once for a short time with a SW field (27.12 MHz) between the 1st and 16th day of pregnancy. The EMR doses were measured thermally by continuously monitoring rectal temperature. Electric power of 50, 70, and 100 W was used. The fetuses were sectioned on day 20, weighed and examined for external visible malformations and spinal and skeletal defects. Preimplantation loss was calculated. HF effects were dependent on the pregnancy phase with the type of malformation dependent on the day of pregnancy at time of exposure. Early exposure usually resulted in death of the embryo while later exposure was dangerous due to heat accumulation in the amniotic sac which is not well perfused. The frequency of malformations and abortion depended on the intensity of radiation; however, a lower threshold at which malformations will occur was found than previously reported. A significant rise was observed only when thermal effects occur. In studies on superficial experimental tumors a much greater effect was found to occur with nonionizing than ionizing radiation, indicating that HF radiation may eventually be used to therapeutically treat malignant tumors. (20 references)

0513 SOME EFFECTS OF EXPOSURE OF THE JAPANESE QUAIL EMBRYO TO 2.45-GHz MICROWAVE RADIATION. (E.) McRee, D. I. (Nat. Inst. Environ. Health Sci., Research Triangle Park, N. C.) P. E. Hamrick, J. Zinkl, P. Thaxton, and C. R. Parkhurst. *Ann. N. Y. Acad. Sci.* 247, 377-390, 1975.

The influence of 2450 MHz CW radiation at normal incubation temperature on cellular differentiation systems of Japanese quail embryos (*Coturnix coturnix japonica*) was studied. The quail was selected for its smaller egg size and shorter development time as compared to the chicken. Gross malformations and hema-

tologic parameters were used to determine biological effects of radiation exposure. Six groups of 57 eggs each were irradiated at a power density (30 mW/cm²) that would maintain temperature during exposure to the same as that of the incubator (37 C). Irradiation lasted for 4 hr in a 40% humidity environment. Groups 1, 2, 3, 4, and 5 were irradiated for 4 hrs each at the end of days 1, 2, 3, 4, and 5 of incubation, resp.; group 6 was exposed for 4 hr on each of the 5 incubation days. Control groups corresponding to each of the exposed groups were handled identically except for the actual irradiation. After exposure, test and control eggs were returned to the incubator to hatch. Two days after hatching began quail were weighed, decapitated, and examined for gross deformities. Blood samples were taken to determine hematocrit, RBC count, WBC count, hemoglobin, and differential WBC percentages. Weights for control and exposed birds were almost identical and differences were small for gross deformities. There were no striking differences in any blood studies for control or exposed groups. No gross malformations attributable to MW irradiation were noted, suggesting that either quail embryos are less sensitive than chicken embryos to radiation, or heat augmented the effects of MWs in previous experiments. (14 references)

0514 EFFECTS OF ELECTROMAGNETIC FIELDS ON FECUNDITY IN THE CHICKEN. (E.) Krueger, W. F. (Dep. Poultry Sci. Electr. Eng., Texas A & M Univ., College Station), A. J. Giarola, J. W. Bradley, and A. Shrekenhamer. *Ann. N. Y. Acad. Sci.* 247, 391-400, 1975.

An evaluation of CW low power VHF and UHF near zone exposure, including ELF E-fields and magnetic fields, on fecundity in the chicken was made. One cock and 4 inbred hybrid females constituted each of the 6 groups of birds used. One group served as controls and the others were exposed as follows: (1) to a 260 MHz UHF field that decreased from 100 to 4 mW during the experiment [E^2/η (square of the E-field strength/intrinsic impedance of free space) decreased from 125 to 5 μ W/cm²]; (2) to a 915 MHz UHF field with available power of 800 mW for 2.5 wk, 0 for 1 wk and 200 mW for the remainder of the experiment ($E^2/\eta = 100 \mu$ W/cm², 0, and 250 μ W/cm², resp.); (3) to a 2.435 GHz MW field excited by a source with an available power of 800 mW ($E^2/\eta = 1000 \mu$ W/cm²); (4) to a 60 Hz ELF E-field with an electric potential of 950 V; and (5) to a 60 Hz low-frequency magnetic field with a mean value of 1.4 G. The chickens were exposed for 12 wk followed by a 4 wk nonexposure period. Daily egg production, feed intake, egg specific gravity, fertility, hatchability, abnormalities, and sex ratio data were collected on each group. Egg production rate decreased for all five groups during the 112 day test period, but hens exposed to UHF and VHF EM fields performed differently from the others. All birds except those exposed to the magnetic field adapted to their new environment after 6-8 wk exposure and egg production stabilized at the new value. Neither fertility nor hatchability was affected by the radiation. No evidence of a

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change in sex ratio was seen except possibly in the magnetic field and no abnormalities attributable to the exposure were noted. Egg shell quality degenerated in the group exposed to 2.435 GHz MWs. (8 references)

- 0515 THRESHOLD EFFECTS OF MICROWAVE RADIATION ON EMBRYO CELL SYSTEMS. (E.) Pyle, S. D. (Dep. Electr. Eng., Univ. Colorado, Boulder), D. Nichols, F. S. Barnes, and E. Gamow. *Ann. N. Y. Acad. Sci.*, 247, 401-407, 1975.

Experiments to determine damage thresholds caused by pulsed MWs on biological systems and to improve understanding of the physical mechanisms associated with these thresholds were reported. Eggs of the zebra fish, *Brachydanio rerio*, were exposed to high PW MW fields at a low duty cycle to minimize heating. Maximum forward power available was ~ 0.5 Mw (1 sec, 2.7 GHz, 20 pps). Zebra fish were chosen because they hatch quickly (4 days), are small, and are transparent enough for the developing embryo to be seen. Incubation, handling, and temperature control experiments were run. In MW irradiated embryos, injury appeared quickly as a small internal bulge which enlarged until it broke with all the embryonic material flowing into the chorionic space. In thermal control experiments, embryos appeared disorganized and opaque after 24 hr. The MW power levels which cause damage are unknown, but the qualitative differences between control and irradiated samples are significant. (1 reference)

Part V. Effects on Behavior

- 0516 INTRODUCTION: EFFECTS ON BEHAVIOR. (E.) Justesen, D. R. (VA Hosp., Kansas City, Mo.). *Ann. N.Y. Acad. Sci.* 247, 408-409, 1975.

To the extent that cognitive processes are part of an organism's reaction to physical events in the environment, a behavioral scientist is needed. In assessment of radiation effects on behavior, interdisciplinary effort is necessary between biologists, engineers and psychologists. In this session attempts were made to impart understanding of some of the technical language of experimental psychology. (1 reference)

- 0517 MICROWAVE DOSE-RESPONSE RELATIONSHIPS ON TWO BEHAVIORAL TASKS. (E.) Galloway, W. D. (Div. Biol. Eff., Bur. Radiol. Health, Rockville, Md.). *Ann. N. Y. Acad. Sci.* 247, 410-416, 1975.

On the assumptions that observed behavioral effects are due to the absorption of MW power within the CNS and that these effects will occur in a dose-related fashion, studies of MW effects on discriminative performance and upon the acquisition of behavior were conducted. Four rhesus monkeys were trained to per-

form discriminative tasks; they were exposed at various time intervals over a 9 mon period with integral dose rates of 5, 10, 15, 20, and 25 W of 2450 MHz CW radiation. There was no suggestion of a radiation induced effect upon performance at any exposure regimen. Two rhesus monkeys were trained at a repeated acquisition task for 39 days before radiation was initiated. Integral dose rates of 10, 15, 20, and 25 W were randomly administered at least twice during the 100 day irradiation series. Duration of radiation was 2 min or until convulsions began. Some evidence of a dose related effect upon performance was revealed, with irradiation at 25 W consistently producing performance deficits. The assumption that the amount of work done upon the CNS can be estimated from the amount of energy absorbed by the head of the subject and/or the assumption that this value would be related to behavioral effects shown are incorrect. No behavioral effects were observed at doses of less than 15 W, while at higher levels skin burns or convulsions resulted without reliably changing performance. Methods for direct measurement of power absorption *in vivo* must be developed before the relationship between CNS irradiation and behavioral changes can be elucidated. (6 references)

- 0518 PRELIMINARY INVESTIGATIONS OF THE EFFECTS OF LOW-LEVEL MICROWAVE RADIATION ON SPONTANEOUS MOTOR ACTIVITY IN RATS. (E.) Roberti, B. (Med. Biol. Lab. TNO, Rijswijk 2100, Netherlands), G. H. Heebels, J. C. M. Hendricx, A. H. A. M. de Greef, and O. L. Wolthuis. *Ann. N.Y. Acad. Sci.* 247, 417-424, 1975.

Wistar rats (160-180 g) were used in experiments to monitor changes in spontaneous motor activity with exposure to low-levels of MW radiation. X-band CW radiation of 10.7 GHz, S-band CW radiation of 3 GHz, and S-band pulsed radiation of 3 GHz were used at 1 mW/cm² power density. MWs at 10 GHz penetrate only a few mm so effects must be due to influences on superficial structures such as skin receptors; at 3 GHz radiation penetrates several cm which can affect the CNS and deep organs in the rat. One group of rats was exposed to each type of radiation for 185 hr and a 4th group was exposed to 3 GHz PW radiation for 17 days. Spontaneous motor activity was measured electronically by dividing movements made by the rat when placed between 2 horizontal metal plates into 6 classes, including rearing, time in upright position, and horizontal respiratory movements. Spontaneous motor activity was measured at the end of each irradiation period, and in the 17 day exposure was also measured after the 5th and 12th days. No significant differences were seen between irradiated and control animals; no deleterious effects of MW radiation were detected. (11 references)

- 0519 EFFECTS OF LOW-LEVEL MICROWAVE RADIATION ON BEHAVIORAL BASELINES. (E.) Thomas, J. R. (Naval Med. Res. Inst., Bethesda, Md.), E. D.

Finch, D. W. Fulk, and L. S. Burch. *Ann. N. Y. Acad. Sci.* 247, 425-432, 1975.

Changes in behavior of animals conditioned to respond to multiple schedules of reinforcement after exposure to low levels of MW radiation were observed. Four male Sprague-Dawley rats maintained at 80% of their free feeding weights were trained by the method of successive approximation to press levers to yield food pellets. They were then exposed to a multiple fixed-ratio, differential reinforcement of low rate (mult FR DRL) schedule for at least 60 sessions before experimental manipulation. The rats were irradiated with 2860 and 9600 MHz pulsed radiation and 2450 MHz CW radiation for 30 min under far-field conditions before experimental sessions 1-2 days/wk. Both CW and PW radiation at all frequencies produced changes in ongoing behavior. There was a marked decrease in response rate associated with the FR schedule and an increase in response rate associated with the DRL schedule. Responding also increased during time-out periods. Results indicate that low-level MW radiation produces effects on the CNS as evidenced by behavioral changes and these changes are influenced by interactions of the organism with the environment. (4 references)

0520 NEURAL FUNCTION AND BEHAVIOR: DEFINING THE RELATIONSHIP. (E.) Frey, A. H. (Randomline, Inc., Huntingdon Valley, Penn.), S. R. Feld, and B. Frey. *Ann. N. Y. Acad. Sci.* 247, 433-439, 1975.

The effects of PW and CW energy on behavior and brain permeability were studied in 2 sets of experiments. In the first, pulsed, CW and sham illumination effects on rats in a shuttle box were compared. One half of the box was shielded from RF energy. The pulsed radiation (1.2 GHz, 0.5 msec, 1000 pps) had a peak power level of 2.1 mW/cm² and average power density of 0.2 mW/cm²; CW average power density was 2.4 mW/cm². The power densities selected were close to the lowest perceptible. Eighteen female Sprague-Dawley rats were randomly assigned to one exposure group and exposed 30 min/day for 4 days. No significant differences were found after 2 days, but differences were significant the last 2 days with the pulse-illuminated group spending 32% of their time in the unshielded half of the box, the sham spending 52%, and controls 64%. The differences between pulsed vs sham and pulsed vs CW groups were statistically significant. This is a behavioral technique which differentiates between pulsed and CW exposure and provides the potential for relating behavioral changes to brain change. In the second experiment, sodium fluorescein, which binds to serum protein when injected into the bloodstream, was used to study brain barriers. Ninety Sprague-Dawley rats were illuminated with MW radiation under the 3 exposure conditions used in the first experiment. They were then injected with the dye, allowed to equilibrate for several minutes, the animal was exsanguinated, and the brain was removed and embedded in gelatin. Fluorescence, which indicates alteration in the permeability of brain tissue barriers, was generally seen at

the diencephalon level of the brain. Effects in the pulsed condition were significantly different from effects in the CW condition and both were different from control. The results indicate that irradiation of a small mammal with low power RF energy affects the brain barrier; it is not possible to conclude that the observed effect was direct, as illumination was not confined solely to the brain. An association is indicated between behavioral modification and brain permeability change when similar RF parameters are employed. (1 reference)

0521 BEHAVIORAL EFFECTS OF PULSED MICROWAVE RADIATION. (E.) Hunt, E. L. (Battelle, Pacific Northwest Lab., Richland, Wash.), N. W. King, and R. D. Phillips. *Ann. N. Y. Acad. Sci.* 247, 440-453, 1975.

Three sets of experiments were performed to study effects of pulsed MW radiation on exploratory activity, swimming, and discrimination performance on a vigilance task. Young adult male Wistar rats were irradiated or sham irradiated with pulsed 2.45 GHz MWs (120 pulses/sec) for 30 min in a multimode resonating cavity. Absorbed dose rates were 6 and 11 mW/g. In investigating effects of exploratory activity, rats were exposed and then placed in an activity apparatus and allowed to explore freely for 1-2 hr. In parallel tests animals were held for one hr postirradiation before activity tests were started to determine whether activity was related to elevation in body temperature produced by the radiation. Immediately after treatment, mean temperature was 40.3 C in exposed rats and 38.6 C in controls; one hr later values were 37.8 C and 38.0 C, resp. In both series of experiments exposed animals exhibited less activity than controls; activity level of controls decreased finally to the same level as irradiated animals. There was no evidence that one hr postirradiation delay attenuated the radiation effect, indicating that the decreased activity level was not directly related to transient hyperthermia produced by MW heating. In swimming performance experiments, trained rats were tested on a repetitive swim task immediately after 30 min exposure at 6.3 mW/g or 24 hr after exposure at 11 mW/g. All exposed animals exhibited a reduction in swimming speed late in the test resulting from a loss of capacity due to fatigue. To test exposure effects on performance of a complex discrimination task, trained rats were tested for 30 min immediately after irradiation at 0, 6.5, and 11 mW/g, and over a 5 day period with a series of irradiation tests. Although animals missed or ignored presentations of positive stimuli immediately after irradiation at either dose rate, a rapid rate of recovery continued throughout the test and was complete for the 6.5 mW/g exposure by the middle of the test period, indicating that performance loss was directly related to MW-induced hyperthermia. MW effects reflected alteration in performance rather than interference with trained skills as both swimming proficiency and accuracy in discrimination response were retained without retraining after nearly lethal irradiation. (15 references)

Part VI. Dosimetry

- 0522 CONTRAST OF DOSE DISTRIBUTION IN PHANTOM HEADS DUE TO APERTURE AND PLANE WAVE SOURCES. (E.) Ho, H. S. (Bur. Radiol. Health, HEW, Rockville, Md.). *Ann. N.Y. Acad. Sci.* 247, 454-472, 1975.

The determination of dose rate patterns in biologic bodies provides a simple, useful indication of the interaction between tissues and EMFs. Theoretical calculations of dose rate patterns for phantom heads of monkeys and humans irradiated by both aperture and plane wave sources were compared. A 5 layered tissue equivalent sphere was also used to simulate the monkey head tissues more closely. A study of the dose rate patterns in the 5 layered head indicated that absorbed EM energy was primarily concentrated in the skin layer with weak penetration of the brain region. This skin heating may have served to mask out penetration of the EM energy into the deeper brain region. Drastic differences were seen when dose rate patterns of phantom heads were compared using the two sources; hot spots present in the plane wave irradiation were not present in aperture treatment and penetration of absorbed EM energy was weaker for the aperture case. The exposure fields of both sources were different, however, so results could not be directly compared. The amount of energy absorbed depended both on subject size and radiation source. The calculations also indicated that for the same exposure field detected by a survey meter, different EM absorptions may occur in a human head according to the source used. Research is needed to determine dose rate patterns in phantom heads that simulate actual heads most closely. Preliminary findings indicate general agreement between calculated and experimental results from aperture exposure. It is concluded that for different radiation sources, direct comparison of biological results by external field measurement may not be dosimetrically valid; for the same power density, the energy absorbed by a human head may vary according to the type of radiation source. (6 references)

- 0523 MICROWAVE ENERGY DISTRIBUTION MEASUREMENTS IN PROXIMITY TO MAN AND THEIR PRACTICAL APPLICATION. (E.) Beischer, D. E. (Naval Aerosp. Med. Res. Lab., Pensacola, Fla.) and V. R. Reno. *Ann. N.Y. Acad. Sci.* 247, 473-480, 1975.

Measurements of MW field strength in the immediate proximity to man were made. Radiation may be scattered, transmitted, reflected or absorbed by the body. A radiation system which furnished an approximate plane wave was used and the radiation scattered by man at $30 \mu\text{W}/\text{cm}^2$ was measured using CW, PW, or swept frequency radiation between 1 and 12.4 GHz. Measurements were obtained in well defined EMFs from a cylinder, a conducting mannequin, man, and a reference field. The maxima of the standing wave in front of man had a different characteristic from the mannequin or metallic cylinder, with the intensity of the maxima diminishing with distance at a much slower rate, possibly due to man's dielectric composition. The parabolas formed by man and the mannequin nearly coincided, indicating that positions of the maxima were

size and shape dependent rather than dependent on the dielectric constant. These measurements have several practical applications: (1) Consideration of the process of reflection and scattering may assist the biologist in planning irradiation experiments with living material; (2) It seems possible to develop quantitative measurements of scattered radiation at both the body surface and interior boundaries of man; (3) Comparisons of scattering by different size objects can furnish valuable information on the validity of purely dimensional scaling; (4) The question of distances between objects necessary to avoid interference by scattering may be solved with the shadow used to advantage for positioning equipment without disturbing the field; (5) Scattering must be considered in reading radiation probes as an isotropic probe will read a variety of values depending on its distance from the sample; and (6) From direct measurements of scattered, reflected, and transmitted radiation, information can be gained about absorbed energy in the biosystem, verifying extrapolations from static models and possibly replacing them. (6 references)

- 0524 A MINIATURE BROAD-BAND ELECTRIC FIELD PROBE. (E.) Bassen, H. (Bur. Radiol. Health, HEW, Rockville, Md.), M. Swicord, and J. Abita. *Ann. N.Y. Acad. Sci.* 247, 481-493, 1975.

A miniature broad-band electric field probe was developed for measuring the total electric field with a flat frequency response from 915 MHz to above 10 GHz in free space. The small probe will also be used for measuring fields within animal tissue or tissue equivalent materials at frequencies below 3 GHz, where the foreshortened wavelength makes miniaturization imperative. The design employs three orthogonal dipoles with discrete diode detectors having high-resistance leads; the latter, which convey the detected signal to appropriate readout electronics, cause minimum scattering of the field and thus do not disturb the isotropicity of the receiver. The basic probe configuration is discussed with respect to isotropic reception and minimal field interaction requirements, dipole array, I-beam configuration, diode detector, high-impedance leads, and fabrication. Data are presented for dipole pattern and polarization tests at 2450 MHz, dynamic response at power densities from 20-100 mW/cm^2 and outputs of 18 and 145 mV, frequency response from 915 MHz to 10 GHz, and crosspolarization of the dipole with the electric field. Probe readout electronics are summarized and planned modifications of the probe are noted. (3 references)

- 0525 MEASUREMENTS OF POWER ABSORPTION BY HUMAN PHANTOMS IMMersed IN RADIO-FREQUENCY FIELDS. (E.) Allen, S. J. (Radiobiol. Div., U.S. Air Force Sch. Aerosp. Med., Brooks Air Force Base, Tex.). *Ann. N.Y. Acad. Sci.* 247, 494-498, 1975.

Experiments were designed to measure the energy absorption of a human phantom exposed to HF band (10,

20, and 30 MHz) RF radiation fields. A rectangular Lucite phantom was loaded with Ringer's solution (8.6 g/l NaCl, 0.3 g/l KCl, and 0.33 g/l CaCl₂). The phantom was centered under the center conductor of the TEM mode RF exposure chamber. Uniform fields exist throughout a 4 x 20 x 2 ft exposure vol above and below the center conductor. The transmitter was operated at a constant power level in the CW mode and 3 sets of data were obtained for each frequency. There was no significant difference between data obtained with 50 W input power and with 13.8 kW input power when each was normalized to 1 mW/cm² incident power density. The technique provides a method of power absorption measurement in simulated far field conditions that can be used for many types of biological specimens. Further experiments will investigate effects of orientation, complex shape, and complex dielectric constants using prolate spheroid models. (4 references)

0526 FIELD MEASUREMENTS, ABSORBED DOSE, AND BIOLOGIC DOSIMETRY OF MICROWAVES. (E.)

Phillips, R. D. (Biol. Dep., Battelle, Pacific Northwest Lab., Richland, Wash.), E. L. Hunt, and N. W. King. *Ann. N. Y. Acad. Sci.* 247, 499-509, 1975.

A comparison was made between the biologic effects produced by two microwave treatment arrangements at equivalent radiation doses: a multimodal resonating cavity system, in which the animal serves as the load and is exposed multilaterally; and a far-field exposure system in an anechoic chamber, in which the animal is exposed unilaterally to a well-defined incident field. Absorbed doses with cavity and far-field exposures were measured calorimetrically for three different sizes of rats. The total energy absorbed in a 1 min exposure for each watt of net cavity power increased with body mass. Mass absorption density (average energy absorbed/g) and area absorption density (average energy absorption/unit total surface area) decreased with an increase in body mass. With far-field exposure, the total energy absorbed/min per mW/cm² also increased with body mass. Mass absorption densities were the same for the two heaviest wt groups and slightly higher for the lightest wt group. Silhouette area absorption densities (average absorption/unit of shadow cross-sectional area) did not change with animal size. Cavity irradiation at an absorbed dose rate of 11.5 mW/g for 30 min resulted in the death of rats within 24 hr; a similar response was observed in rats irradiated unilaterally in the far field at 8.3 mW/g for 30 min. With cavity irradiation, functional changes occurred within 1-3 hr after a 30 min exposure at 6.5-11.0 mW/g; these consisted of thermoregulatory overcompensation, a lowered metabolic rate, bradycardia, irregular heart rate, and incomplete heart blockage. None of these functional alterations were observed following 30 min far-field irradiations at comparable dose rates. Latency to convulsions, measured during cavity exposure of Wistar rats and C57BL/6J mice, was correlated with the average energy absorbed/unit mass. Comparison of energy absorption by rats and water models yielded

different results for cavity and far-field exposures. With cavity irradiations, the mass absorption density is the appropriate unit for estimating absorbed doses with models. In unilateral far-field irradiations, the silhouette area absorption density is useful. These studies indicate that a safety standard based on incident field densities and on experimental data for far-field exposures may not be applicable under conditions of multilateral irradiation. (19 references)

0527 A PYROELECTRIC PROBE FOR MEASUREMENT OF MICROWAVE POWER DENSITY UNDER FAR-FIELD CONDITIONS. (E.) Huddleston, G. K. (Sch. Electr. Eng., Georgia Inst. Technol., Atlanta) and D. I. McRee. *Ann. N. Y. Acad. Sci.* 247, 510-526, 1975.

In experiments in which a biologic specimen is irradiated with a transverse electromagnetic (TEM) wave, the field parameter of interest is the EM power density (mW/cm²) at the location of the specimen insertion. Investigative results are reported on the use of pyroelectric material in the realization of a probe to measure power density in the 2-12 GHz frequency band. This type of probe operates on the principle of energy absorption in a lossy substance rather than as an antenna *per se*. A pyroelectric crystal with a lossy substance applied to it serves as the absorber of MW energy and the detector of the same via the pyroelectric effect. A mathematical model of a pyroelectric detector is included together with a description of lossless and lossy probes and their associated instrumentation. The responses of these probes are compared with respect to square wave amplitude-modulated MW radiation at selected frequencies in the 2-12 GHz frequency band under far-field (TEM wave) conditions. The maximum responsivity (2480 mV/mW/cm²) of the lossless probe was obtained at 8.2 GHz. Addition of lossy materials to the crystal enhanced the bandwidth of the pyroelectric probe but at the expense of maximum responsivity. Additional work is necessary to develop the potential of such probes fully. Further studies should include the development of an implantable pyroelectric probe for measuring volumetric power density inside biologic materials. (9 references)

0528 DISCUSSION PAPER: FIBEROPTIC LIQUID CRYSTAL PROBE FOR ABSORBED RADIO-FREQUENCY POWER AND TEMPERATURE MEASUREMENT IN TISSUE DURING IRRADIATION. (E.) Johnson, C. C. (Dep. Bioeng., Univ. Utah, Salt Lake City), C. H. Durney, J. L. Lords, T. C. Rozzell, and G. K. Livingston. *Ann. N.Y. Acad. Sci.* 247, 527-531, 1975.

A temperature probe, which employs fiber optics to transmit information to and from a liquid crystal sensor tip, has been designed to be transparent to EMFs in tissue. The probe is sheathed in polyvinyl chloride and the liquid crystal is encapsulated between 2 nested glass cups. The device should solve many dosimetry problems and should allow calculation

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of local absorbed RF power density by measuring the rate of change of tissue temperature rise. The probe has a sensitivity of 20-40 mV/C. It gives reproducible results over an 8 hr period with absolute and relative temperature calibrations of 0.25 and 0.1 C. It has been shown to measure the rate of tissue temperature change with time accurately, and to perturb the tissue fields minimally. Tests are being performed in various laboratories to identify problems which may arise with different types of biological experiments. (No references)

0529 DISCUSSION PAPER: STRONG DEPENDENCE OF WHOLE ANIMAL ABSORPTION ON POLARIZATION AND FREQUENCY OF RADIO-FREQUENCY ENERGY. (E.) Gandhi, O. P. (Electr. Eng. Dep., Univ. Utah., Salt Lake City). *Ann. N. Y. Acad. Sci.* 247, 532-538, 1975.

A 2-plate stripline was used to generate plane wave fields to measure wide-band RF absorption of biological systems. Absorption characteristics of 96 390 g Wistar rats, 25 g mice and brain phantom prolate spheroid bodies were measured at 100 frequencies in the 285-4000 MHz region. For the 3 orientations $E \parallel \hat{a}$, $H \parallel \hat{a}$, and $k \parallel \hat{a}$, a strong orientation effect is observed with $E \parallel \hat{a}$ being the most absorbing. Peak absorption in the $E \parallel \hat{a}$ configuration occurs at the lowest frequency of the 3 orientations. Experiments with free space plane wave irradiation at 1700 MHz to heat saline-filled prolate spheroid bodies collaborate the main features of the stripline results. The values of the relative absorption coefficient S measured by the stripline are consistent with the value obtained for the free space irradiation, confirming the viability of using the stripline to determine broadband absorption characteristics. RF power deposition is found to vary significantly with orientation and frequency. Absorption at resonance for the $E \parallel \hat{a}$ orientation may be greater by a factor of 10 or more than for other configurations. By extrapolation, important frequencies for absorption for humans are 40-55 MHz for $E \parallel \hat{a}$ and 135-165 MHz for the other 2 configurations, implying that whole animal absorption is size and shape dependent. (5 references)

0530 FUTURE RESEARCH DIRECTIONS AND NEEDS IN BIOLOGIC ELECTROMAGNETIC RADIATION RESEARCH. (E.) Guy, A. W. (Sch. Med., Univ. Washington, Seattle). *Ann. N. Y. Acad. Sci.* 247, 539-545, 1975.

There is an urgent need for international cooperation in developing a quantitative scientific data base, from both a physical and biological standpoint, on which to evaluate biological hazards of EMR. The interaction of EM fields with biologic tissues is a function of the magnitude of the electric and magnetic fields, stored energy in these fields, tissue configuration and composition, frequency, environmental factors, etc. There is a lack of knowledge concerning the internal field

distributions which produce radiation effects in biologic objects. The effect of biological instrumentation on the EM fields in the animals and vice versa is important, but little is known about it. More must be learned about extrapolating *in vitro* studies to the establishing of safety standards. International adoption of the following suggestions would help resolve and quantify problems which have developed: (1) techniques for measuring near-zone field components should be standardized; (2) methods to determine what field, absorbed power density, or current density will be induced by various fields with known parameters should be established; (3) standardized EM sources and exposure chambers should be developed; (4) standard biological specimens, containers, and restraining apparatus should be agreed on; (5) methods to record biological potentials without disturbing the induced field should be improved; and (6) rationale for quantitative extrapolation of information from animal exposure to human exposure should be developed. A working team of biological and physical scientists and engineers with a thorough training in the field are necessary, as are good laboratory facilities. Close collaboration between laboratories and among nations should be encouraged for maximum utilization of specialities and facilities available. (1 reference)

0531 CURRENT MICROWAVE STUDIES. APPENDIX I. (E.) Schwan, H. P. (Dep. Biomed. Eng., Univ. Pennsylvania, Philadelphia) and H. N. Kritikos. *Off. Naval Res. Rep.*, Contract No. N00014-67-A 0216-0015, 1971, 10 p, NTIS: AD/A-001 409.

Two sets of experiments have been performed, the first to compare and evaluate pulsed vs continued fields of the same average power and the second to study the possibility of creating "hot spots" in tissues by MW irradiation. Studying field evoked force effects, including pearl chain formation and other effects which alternating fields have on small particles, it was concluded that unless fundamental thermodynamic principles are violated, any reversible effect takes place in accordance with the average value of the applied field, and continuous fields are the most efficient. In the second study a computer was programmed to evaluate the heating potential in a spherical object filled with tissue which has dielectric properties similar to cerebral tissues. The computer was to search for "hot spots" in this model of the brain. Using a head with a radius of 5 cm (monkey size), a hot spot of substantial magnitude was created inside the head and occurred from 150 to 3000 MHz. When a larger model (10 cm radius) typical of man was considered, the hottest spot was always at the surface of the head facing the radiation source. Thus, for small objects hot spots definitely exist, but none are anticipated for the human head as MWs become too attenuated to create resonances. Little can be learned about MW hazards for man from small animal experiments. (No references)

- 0532 EFFECT OF 2450 MHz MICROWAVE RADIATION ON
HORSE RADISH PEROXIDASE. (E.) Henderson,
H. M. (Dep. Food Sci., Univ. Manitoba, Winnipeg,
Canada), K. Hergenroeder, and S. S. Stuchly. *J.*
Microwave Power, 10(1):27-35, 1975.

To test the possible use of MWs in dry blanching techniques, their effects on peroxidase, which has high thermostability and is involved in undesirable oxidative changes in food flavoring, was studied. Solutions (2.0 g/ml water) of horseradish peroxidase were made up immediately prior to use. Control samples were run identically to test samples in the same MW equipment, but in the absence of MW radiation. The sample system was designed to maintain sample temperature at 25 C during the exposure period and to allow measurement of MW power dissipated in the sample. The peroxidase was subject to MW radiation of a power density range of 62.5 - 375 W/cm² from 5 to 40 min. Temperatures were maintained within ± 2 C. Exposure to MW radiation for 5 min resulted in steadily decreasing activity with a 20% loss on exposure to 375 W/cm². Longer time periods and higher power densities resulted in greater losses. Inactivation was 96.2% at 250 W/cm² and 30 min exposure; however, total inactivation was never obtained. There were no statistically significant differences between MW power absorption and conventional heating methods. Although the sample temperature was macroscopically kept constant at 25 C, enzyme destruction could conceivably be due to local heat denaturation. Significant inactivation is possible at room temperature, but the required radiation doses are very high and have no practical utilization. (24 references)

- 0533 EVALUATION OF THE EFFECT OF AN ELECTRO-
MAGNETIC FIELD OF THE MODERATE WAVE
LENGTH RANGE ON HEALTH IN POPULATED AREAS. (Rus.)
Mukharskii, M. S. (A. N. Marzeev Res. Inst. Gen.
Communal Hyg., Kiev, USSR). *Vrach. Delo* (1):118-
121, 1975.

Measurements made at distances of 100-1000 m from the antennas of radio stations transmitting at moderate wave lengths showed that field intensities ranged from 0.2-56 W/m. Studies of male albino rats exposed continuously to the same type of radiation for 120 days at intensities of 5, 10, 20, 35, and 140 W/m demonstrated that weight gains were inversely related to field intensity; this effect was most evident in the third month of the experiment. Field intensities of 20, 35, and 140 W/m inhibited the development of conditioned reflexes to a number of weak stimuli. This effect depended upon the length of exposure and was most pronounced at the greatest field intensity. While this radiation had no effect on the RBC, it produced significant changes in the WBC at an intensity of 140 W/m and in the eosinophil count at intensities of 20 W/m or greater. Cholinesterase activities in the blood decreased significantly in rats irradiated with 140 W/m for more than 2 mon; normalization occurred 2 mon after exposure was discontinued. Exposure to an intensity of 140 W/m also reduced blood glucose levels and liver gly-

cogen contents and increased liver lactic acid contents, suggesting that RF radiation causes disorders in glycogen synthesis in the liver. Morphological examination of the rats revealed dystrophic changes in the nervous system, parenchyma of organs, and regenerative epithelium of the testes. Proliferative changes in the brain and reticuloendothelial cells in the liver and hyperplasia of follicles in the spleen with the appearance of less mature cells suggests that exposure to radio waves interferes with protective and adaptive processes in the body. Examinations of children and adults living near radio stations broadcasting at moderate wave lengths confirm that this radiation has a deleterious effect on the CNS in children, interferes with immunity, and has some tendency to cause disorders in protein metabolism. On the basis of this study, it is proposed that the maximum permissible field intensity for populated areas be 10 W/m. (No references)

- 0534 MICROWAVES AND BEHAVIOR. (E.) Justesen,
D. R. (Lab. Exp. Neuropsychol., VA Hosp.,
Kansas City, Mo.). *Am. Psychol.* 30(3):391-401,
1975.

Psychologists are interested in biological studies of EMFs because the CNS is considered to be a biological amplifier whose behavioral response is a very sensitive indicator of reactivity to EM energy. Scientists, with no satisfactory theory of the role of intrinsic electrical events in organisms, lack an understanding of basic electrobiological mechanisms. Photon energies of RF radiation are very small, but exposure to high densities can result in excessive heating. MW energy penetrates deeply into tissue and may do much damage before being detected. Eastern Europeans have interpreted results of animal studies and case histories of people chronically exposed to low level MW radiation as resulting in a neurasthenic syndrome. No reliable evidence of this syndrome was ever reported in the U. S. However, Frey has reported that humans can "hear" MW energy at levels much lower than those of current safety standards, probably due to some form of thermoacoustic transduction. Also it has been shown that the total energy absorbed by phantom models is sometimes much higher than that predicted by measuring the density of the MW field. There may be EM receptor and transmitter systems in the human comparable to or greater than either the visual or auditory although there are no known EM emissions to warrant more than guarded speculations. (47 references)

- 0535 HEALTH ASPECTS OF RADIOFREQUENCY ELECTRO-
MAGNETIC RADIATION. (Ital.) Grandolfo, M.
(Higher Inst. Health, Rome, Italy). *Res. Rep.*, No.
N75 13511, 1974, 29p.

The dielectric properties of various tissues exposed to MWs, the pathological effects of MW exposure, and current standards for MW exposure are reviewed.

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Biological Effects Electromagnetic
Radiation 11(2), June 1975

While empirical expressions have been formulated to calculate the dielectric constant, ϵ , for tissues containing large amounts of water (blood and some fatty tissue), this cannot be done for tissues containing little water (subcutaneous fat, bone, and bone marrow) because of inadequate knowledge of the various forms of water "bound" to the surface of macromolecular constituents of these tissues. When the dielectric properties of a tissue are known, it is possible to evaluate absorption coefficients and the depth to which radiation penetrates. The index of effective penetration, defined as the ratio between total energy absorbed and incident energy, is also useful in analyzing these phenomena. Exposure to MW radiation can produce changes in the blood, gonads, eyes, and CNS as well as serological changes. These changes are attributed primarily to the conversion of MW radiation into heat, but nonthermal effects have also been implicated. In the USA and many Western European countries, 10 mW/cm² is recommended as the maximum acceptable level for a continuous 8 hr work day, and 1 mW/cm² is recommended by some organizations as the maximum level for continuous exposure or for the civilian population. In the Soviet Union and some Central European countries, lower values are recommended because more emphasis is placed on the importance of nonthermal effects of MW radiation. (8 references)

0536 MICROWAVE OVENS: WHAT'S COOKING? (E.)
Mennie, D. (Assoc. Ed., *IEEE Spectrum*,
Piscataway, N.J.). *IEEE Spectrum*, 34-39, March,
1975.

MW ovens are becoming a normal household appliance. They are much more efficient than standard ranges because they heat only food, which has a high water content, while electrically neutral containers and cookware remain cool. There is much controversy, led by Consumer's Union (CU), over acceptable guidelines for MW ovens due to lack of consistent repeatable results related to longterm biological effects of exposure to low level radiation. Work is now being coordinated by OTP to assess biological hazards of NIR emphasizing low level effects over extended periods of time. CU wants a warning label on every oven to include: (1) warning against operating the oven empty, (2) instructions to unplug after use, (3) instructions on the importance of clean door seals, (4) warning to those with pacemakers, (5) instructions on the importance of keeping the face away from the door when the oven is on, and (6) warning against use by children. The Association of Home Appliance Manufacturers (AHAM) objected and presented guidelines to place warnings in the first 10 pages of the users' manual. The BRH is evaluating all proposals and will announce legally binding recommendations evolving from all suggestions. (No references)

0537 EFFECT OF MICROWAVE RADIATION ON THE CON-
TENTS OF COPPER, IRON, AND COBALT AND
METALLOPROTEINS BOUND TO THEM IN THE ORGANS AND TIS-

SUES OF EXPERIMENTAL ANIMALS. (Rus.) Mints, S. M.
(Med. Inst., Ivano-Frankovsk, USSR) and V. G. Lazaro-
vich. *Gig. Tr. Prof. Zaböl.* (2):54-55, 1975.

Albino rats were exposed for 10 min/day to 60 mW/cm² SHF ($\lambda = 12.6$ cm) radiation for 28 days. By day 14, the Fe content of the liver had increased by 28%, apparently due to decreases in the Fe content of muscle and blood and to a decrease in the Fe saturation of transferrin in the serum. The Cu content of muscle and blood increased more than 1.5-fold, while that of bone decreased throughout the experiment. No appreciable change occurred in the Cu content of the liver or serum ceruloplasmin activity. Blood and bone Co contents decreased significantly. During the first 14 days, the Co content of liver and muscle decreased and then, toward the end of the experiment, increased but failed to reach normal levels. It is suggested that radiation induced changes in Fe, Cu, Co, and metalloprotein metabolism are due to radiation induced disorders in hematopoiesis and protein and lipid metabolism and to some enzymatic and functional changes. (6 references)

0538 MYSTERY. (E.) Aaronson, T. (no affil.).
Our World in Peril: An Environment Review,
S. Novick and D. Cottrell, Ed., Fawcett Premier Pub-
lishers, pp 256-270, 1971.

This article for an environmental review book summarized existing knowledge of MW radiation and explained the difference between U. S. and USSR standards. It pointed out the increasing use of MW radiation, in particular in MW ovens and emissions from TV antennas, and suggested that concentrated research should be undertaken to find what levels may be a potential danger to human health. (24 references)

0539 THE SAFE TREATMENT OF FOOD SUPPLIES WITH
HIGH-FREQUENCY HEAT. (Ger.) Hafner, T.
(no affil.). *Brown Boveri Mitt.* 62(1/2):52-55, 1975.

From pilot plant experiments on wheat and rice, it has been demonstrated that these food products can be successfully sterilized by HF heating. Although the initial temperature of the grain can vary, the temperature at the outlet of the HF generator should be held constant between 60 and 66 C to kill off insects, insect eggs, and molds. The grain must then be cooled to room temperatures below 45 C. No changes occur in the appearance of the grain or in its vitamin content, germination, or baking and cooking properties. Excellent results have also been obtained with both packaged and unpackaged flour, flour products, and oat flakes. The amount of heat required for sterilization depends upon the dielectric constant of the material and the loss factor. Depending upon the dimensions of the condenser, the HF generators operate at frequencies of 13.56 or 27.12 MHz and are provided with filters to suppress harmonic frequencies. Before heating in

the HF generator, grain must be pretreated to remove foreign material and metals to prevent obstruction of the electrodes and interference with the high-frequency field. (No references)

- 0540 EFFECT OF MAGNETIC, ELECTRICAL, AND GRAVITATIONAL FIELDS ON THE TUNNEL BUILDING OF TERMITES. (Ger.) Becker, G. (Fed. Inst. Material Testing, Berlin-Dahlem, Germany). *Umsch. Wiss. Tech.* 75(6):183-185, 1975.

It has been demonstrated that the directions in which termites build their tunnels can be changed by using a Helmholtz coil to compensate for or change the direction of the earth's magnetic field. Among other factors, the feeding activity of termites is apparently affected by "atmospherics" (10 kHz radiation from lightning discharges). No relation has been found between their feeding activity and tunnel building, but both activities are affected by various physical factors, particularly changes in electrical field. When termites are shielded with aluminium plates or copper sheets, tunnel building in a vertical perpendicular upward direction is significantly reduced while feeding activity follows a different pattern. The effect of slight changes in the magnetic field on tunnel building has yet to be investigated. (8 references)

- 0541 THE EFFECT OF A HIGH-INTENSITY SUPER HIGH FREQUENCY FIELD ON BLOOD CLOTTING. (Rus.) Ivanov, V. I. (no affil.), B. V. Maleniuk, and L. N. Kriukova. *Voen. Med. Zh.* (5):54-55, 1974.

Blood clotting parameters were studied in ten 3-year-old mongrel dogs, weighing 11 - 13 kg, before and 10 min to 30 days after a single exposure to a pulsed SHF field (intensity 200 mW/cm², $\lambda = 3$ cm) for 5 min. The clotting time, clot retraction, platelet count, recalcification time, heparin tolerance, prothrombin time, fibrinogen content, and true heparin values were determined. These parameters returned to their original values by day 15 at the earliest and, in some cases, had not yet completely normalized by day 30. The changes were phase-like in nature: a tendency toward hypocoagulation after 10 min, after 2 hr, and again on day 8. A gradual decrease in the prothrombin time may have been caused by a drop in true heparin. It is suggested that radiation-induced changes in blood clotting might be secondary to disorders in CNS regulation. (No references)

- 0542 MICROWAVE THERAPY IN THE DECIMETER RANGE OF PATIENTS WITH RHEUMATOID ARTHRITIS. (Rus.) Tsarfis, I. G. (Inst. Balneol., Physiother., Moscow, USSR), A. A. Fiveiskii, V. D. Grigorieva, I. F. Rabotalova and G. V. Vasilieva. *Vopr. Kurortol. Fizioter. Lech. Fiz. Kult.* (5):411-415, 1974.

One hundred patients with rheumatoid arthritis (43

exudative and 57 proliferative cases) with a 1-20 yr history of the disease were exposed to MW radiation (65 cm, 460 MHz) at 40 - 55 W for no more than 25 min during 12 - 15 daily sessions. A Soviet-made Volna-2 apparatus was used with a rectangular 17 x 34 cm emitter. The distance between the emitter and the exposed area (D₁₀ - L₄ area of the adrenal glands, the solar plexus and affected joints) was 3 - 4 cm. The cardio-vascular system was affected in most of the cases (myocardiosis, atherosclerotic cardiosclerosis, high blood pressure and thyrotoxicosis). As a result of the treatment, the easing of pain and an increase in the bioelectrical activity was observed in 76% of the patients. The therapeutic effect of the MW irradiation was accompanied in most of the patients by an improvement of the glucocorticoid function of the adrenal glands, activation of sympathico-adrenal system, an increase in the bioelectrical activity of the skeleton muscles and electrical activity of the heart. (No references)

- 0543 THE EFFECT OF MICROWAVE THERAPY IN THE CENTIMETER RANGE ON VEGETATIVE FUNCTIONS IN PATIENTS WITH MULTIPLE SCLEROSIS. (Rus.) Starostenko, L. I. (Belorussian Inst. Post-Grad. Med. Stud., Minsk, USSR), G. E. Bagel and I. I. Kardash. *Vopr. Kurortol. Fizioter. Lech. Fiz. Kult.* (3):230-233, 1974.

Twenty patients aged 20 - 40 years with multiple sclerosis were exposed to MW irradiation of the upper cervical sympathetic ganglions at 3 - 5 W power level for 2 - 5 min during 5 - 6 sessions. Ten patients had ataxia, intention tremor, scanning speech, hypotony and incoordination; six had symptoms of ataxia but could walk without help; four patients had slight ataxic disorders. Measurements were taken of the arterial pressure, cardiovascular reflexes, diagnostic dionine-adrenaline electrophoresis, histamine level in the blood, and ECG before and after the exposure. The results indicate that the arterial blood pressure went down from 170/80 - 110/70 mm before the treatment, to 130/80 - 100/70, after. At the same time, headaches and sympathico-adrenal crises disappeared, and the sensation of heat or chill in the extremities was relieved. A significant decrease was observed in the results of galvano-adrenal tests from 3.8 ± 0.3 cm² before the treatment, to 2.5 ± 0.25 cm² after (norm, 2.1 ± 0.1 cm²). The time of the reaction went down from 98.3 ± 5.3 min to 60.4 ± 4.6 min (norm, 57.7 ± 4.3 min). ECG tracings showed changes in 11 patients, mostly in the alpha rhythm. It is suggested that low-dosage MW therapy in the cm wavelength range has a beneficial effect on patients and is to be recommended as part of combined therapy for predominantly cerebellar multiple sclerosis to relieve vegetative disorders. (17 references)

- 0544 MICROWAVE LENS EFFECTS IN HUMANS; II. RESULTS OF FIVE-YEAR SURVEY. (E.) Appleton, B. (Walter Reed Army Med. Cent., Washington,

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D.C.), S. Hirsch, R. O. Kinion, M. Soles, G. C. McCrossan, and R. M. Neidlinger. *Arch. Ophthalmol.* 93(4):257-258, 1975.

Military active duty or civilian employees of the Department of the Army involved in work with MW equipment since 1943 have been given semiannual biomicroscopic examination of the lens of the eye. These examinations were given to 2343 subjects from November 1968 to September 1973. All personnel had histories of working with equipment using MWs, lasers, xenon arcs, UV lights, or welding equipment, or were in occupations considered eye-hazardous but not involving exposure to EM radiation. Controls were individuals who never worked with or near this equipment. Examiners were not aware of the exposure history of the subjects. Results showed no difference between the two groups. Conclusions are: (1) no lens damage due to MW radiation from military equipment occurred, and (2) the existing $10\text{mW}/\text{cm}^2$ safety level and the degree to which it is enforced is adequate to protect humans from MW lens effects. (3 references)

0545 THE EFFECT OF SUPERHIGH FREQUENCY FIELD ON THE ACTIVITY OF CERTAIN ENZYMES AND PYRIDOXINE CONTENT IN THE ORGANS OF ALBINO RATS. (Rus.) Minaiev, V. V. (I. P. Pavlov Riazan' Med. Inst., USSR), N. V. Zhdanovich, Y. F. Udalov, and O. I. Bazilevich. *Gig. Sanit.* (3):11-14, 1975.

The effect of the SHF field on vitamin metabolism was studied in 48 albino male rats weighing 140-150 g on a normal diet. Twenty-four animals were given daily 4-desoxypyridoxine (25 mg/kg) to produce pyridoxine deficiency. Half the animals from each group were exposed to 2,000 MHz at $570\ \mu\text{W}/\text{cm}^2$ for three hours. The results indicate the SHF exposure reduced pyridoxine content in the blood, brain, kidneys and heart, while increasing it in the skeletal muscles. In vitamin B₆ deficient animals, SHF field induced the redistribution of pyridoxine in the body: pyridoxine content rose in the brain tissues, heart and muscles, while it fell in the liver, kidneys and blood. In the exposed animals, the activity of aspartase-aminotransferase decreased while that of alanine-aminotransferase increased. In the vitamin deficient animals, the activity of both enzymes tended to decrease. The activity of succinic dehydrogenase fell under the action of SHF field, but pyridoxine deficiency did not affect the enzyme activity. It is suggested that continuous exposure to SHF fields may reduce vitamin supply to the organism. (9 references)

0546 THE EFFECT OF UHF, SHF, ULTRASOUND AND ULTRASOUND IN COMBINATION WITH MICROWAVE THERAPY ON THE PROTEIN CONTENT IN THE BLOOD SERUM OF PATIENTS WITH CHRONIC TONSILITIS. (Rus.) Krushevskaya, I. I. (Minsk Med. Inst., USSR) *Zh. Ushn. Nos. Gorl. Bolezn.* (3):69-71, 1974.

Studies of the changes in the albumin composition of

sera were conducted on 120 children aged 6-15 years with chronic tonsillitis treated with UHF, SHF, ultrasound (US) and US in combination with MWs. The children were divided into 5 groups: (1) 20 controls; (2) 25 children treated with UHF; (3) 25 children treated with SHF; (4) 25 treated with US (5) 45 treated with US in combination with MWs. Proteinograms of the healthy children showed the average total protein content at 7.53 g%; albumins, 57.46%; α_1 , α_2 , β & γ globulins, 3.21, 9.76, 11.90 and 17.49, resp.; albumin/globulin coefficient was 1.36. Before the treatment, the children with decompensation form of chronic tonsillitis had elevated protein content of 9.73 g%; decrease in the albumin content to 47.9%; increase in α -globulins to 7.1%, α_2 -globulins to 10.77%; α -globulin fraction was up to 20.71 - 23.93%. Thirty-seven patients had a/g coefficient down to 0.95. Fourteen days after the treatment the proteinograms of the children with tonsillitis approached those of the healthy children in all the groups. Particularly good results were obtained in group 5 where 39 patients showed improvement. It is suggested that US in combination with MW is the most effective method of treating chronic tonsillitis. (11 references)

0547 EXPRESS METHOD FOR VISUALIZING THE STRUCTURE OF THE SHF FIELD. (Rus.) Sevastianov, V. V. (no affil.) *Voen. Med. Zh.* (12):53-54, 1974.

Express method for visualizing SHF structure is based on the ability of cobalt chloride mixed with hemamethylenetetramine ($\text{CoCl}_2 \cdot 5\text{H}_2\text{O} + \text{C}_6\text{H}_{12}\text{N}_4$) to change its color from red to blue when exposed to an EM field. SHF-sensitive thermoactive paper was developed by impregnating chromatographic paper with an aqueous solution of cobalt chloride. Exposure to SHF radiation altered the moisture content of the test paper and consequently its color. Tests showed that distinct indications of SHF field were visible when the paper was exposed at 500-550 mW/cm^2 for 2 min. and at 140-150 mW/cm^2 for 4 min. It is suggested that the method can be effectively employed for assessing SHF structures in the emitter zone. (7 references)

0548 THE EFFECT OF ELECTROMAGNETIC RADIATION ON THE FUNCTION OF THE OPTIC NERVE. (Rus.) Melnikova, S. I. (Kharkov Inst. Labour Hyg. Occupat. Dis., USSR) and G. I. Nemtseiev. *Vestn. Oftalmol.* (6):82-84, 1974.

Studies were made of the function of the optic nerve in workers exposed to EM fields, mechanical vibrations, and nitrocompounds. Chronoperimetric techniques were used to determine the limits of visual perception and the early stage of the loss of conductivity in the optic nerve (parabiosis). No significant difference was found in the limits of the field of vision of the 17 operators exposed to UHF radiation at TV retransmitting facilities and 105 unexposed controls. However, 11 of the exposed operators exhibited a shorter reaction time in all the meridians.

No deviations from the norm were observed in the 15 operators of HF hardening installations either in the field of vision or the reaction time. The findings indicate that occupational exposure to mechanical vibrations or nitrocompounds results in the conduction disorders in the peripheral sections of the field of vision. (6 references)

0549 MICROWAVE AND INFRA-RED EFFECTS ON HEART RATE, RESPIRATION RATE AND SUBCUTANEOUS TEMPERATURE OF THE RABBIT. (E.) Birenbaum, L. (Dep. Electr. Eng. Electrophys., Polytech. Inst. New York, Farmingdale), I. T. Kaplan, W. Metlay, S. W. Rosenthal, and M. M. Zaret. *J. Microwave Power* 10(1): 3-18, 1975.

The dorsal aspect of the head of unanesthetized New Zealand albino rabbits was irradiated with MWs (CW, 2.4 GHz) at power levels from 0-80 mW/cm². Respiration rate, heart rate, and s.c. temperature were monitored during the 10 min preirradiation period and during irradiation and the rates of increase were greatest at the highest power levels. Increases in respiration rate (9.39 breaths/min at 80 mW/cm²) were 20 times greater than those in the heart rate (0.32 beats/min at 80 mW/cm²). The effects of CWs and pulsed MWs (2.8 GHz, 20 mW/cm² average power level) were compared by exposing the entire dorsal surface to pulsed MWs and CWs in counterbalanced order. The respiration rate and temperature increased markedly during the 20 min exposure period, while the heart rate remained nearly constant. Differences in the responses to CW and pulsed irradiation were not significant. CW 2.4 GHz MW and infrared (IR) whole back irradiations were carried out at 0, 10, and 20 mW/cm². Heart and respiration response to CW MWs and to IR were substantially the same; in contrast, s.c. temperature increased more rapidly and reached higher values with IR. This result is consistent with the finding that IR is absorbed near the surface to a greater degree than MWs. Differences between the 0 and 10 mW/cm² MW respiration and heart response, as well as a difference between the 0 and 10 mW/cm² IR respiration rate response, indicate that 10 mW/cm² is not athermal for the rabbit. This is presumably the first demonstration of a physiological response to 10 mW/cm². (21 references)

0550 THERMOREGULATORY, METABOLIC, AND CARDIOVASCULAR RESPONSE OF RATS TO MICROWAVES. (E.) Phillips, R. D. (Battelle, Pacific Northwest Lab., Richland, Wash.), E. L. Hunt, R. D. Castro, and N. W. King. *J. Appl. Physiol.* 38(4):630-635, 1975.

The physiological response of rats to MW exposure at doses within the limits of tolerance for survival, i.e., at the basal metabolic rate reported for rats, at the metabolic rate for alert but unexcited rats, and at a rate 2.5 times the basal rate, near the

upper limit of tolerance for survival, was characterized. Young adult male Wistar rats underwent adaption for 47 hr over a 4 wk period, and were then exposed to MWs in a multimodal resonating cavity. They were exposed for 30 min at 27.7 cal/min (4.5 mW/g), 40.1 cal/min (6.5 mW/g), and 68.2 cal/min (11.1 mW/g). Ten animals were used for each dose and paired irradiated and control rats were given simultaneous physiological measurements after exposure. Measurements included colonic temperature, skin temperature, oxygen consumption, CO₂ production, respiratory quotient, and heart rate, monitored continuously from 10 min to 5 hr after exposure was completed. A radiation dose of 27.7 cal/min had no effect on functions measured beyond a transient increase in skin and colonic temperatures. At 40.1 cal/min colonic temperature elevation was followed by overcompensation for 3 hr, changes in cardiovascular function, and a depressed metabolic rate, indicated by change in the rate of oxygen consumption. Physiological response at 68.2 cal/min was more severe, with colonic temperature of 42.4 C at the end of exposure, near the upper survival limit for the rat. A pronounced overcompensation was observed with body temperature less than controls for most of the 5 hr period. Skin temperature was also lower, oxygen consumption and CO₂ production were depressed, and pronounced cardiovascular changes were observed, including bradycardia followed by tachycardia and incomplete heart block. This was a consequence of excessive heating by irradiation and was caused by the action of toxic materials, by elevated serum potassium, or by myocardial ischemia. (40 references)

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0126 EFFECT OF MICROWAVES ON CNS, LIVER, AND HEART. Albert, E. N. (Sch. Med., George Washington Univ., Washington, D. C.).

See CR 0060, Volume I(2), for description of this research. (Renewed 10/74-9/75)

Supporting Agency:HEW, Public Health Serv.

0127 ELECTROMAGNETIC FIELDS GENERATED FROM NEURONAL ACTIVITY. Anninos, P. A. (Sch. Med., Univ. California, Los Angeles).

This project is part of a broader program whose summary states: The primary functions carried out under this grant include the development of statistical and mathematical methods of aid to medical research; the provision of a computing system to support medical research; and the development of programs and techniques to make the use of the computer more effective. (9/73-8/74)

Supporting Agency:HEW, Public Health Serv.

0128 NON-THERMAL EFFECTS OF MICROWAVE RADIATION ON THE GROWTH, DEVELOPMENT AND BEHAVIOR OF BIOLOGICAL SYSTEMS. Barnes, F. S.; Gamow, E. I. (Sch. Eng., Univ. Colorado, Boulder).

See CR 0082, Volume I(3), for description of this research. (Renewed 7/74-6/75)

Supporting Agency:U. S. Dep. Def., Air Force

0129 THE EFFECTS OF EXTREMELY LOW FREQUENCY (ELF) RADIATION ON MAN. Beischer, D. E.; Grissett, J. D. (Aerosp. Med. Res. Lab., Pensacola, Fla.).

See CR 0059, Volume I(2), for description of this research. (Renewed 7/74-6/75)

Supporting Agency:U. S. Dep. Def., Navy

0130 EFFECTS OF MICROWAVE RADIATION ON NAVAL PERSONNEL. Beischer, D. E.; Reno, V. R. (Aerosp. Med. Res. Lab., Pensacola, Fla.).

See CR 0019, Volume I(1), for description of this research. (Renewed 7/74-6/75)

Supporting Agency:U. S. Dep. Def., Navy

0131 BIOLOGICAL EFFECTS OF VLF BAND ELECTROMAGNETIC RADIATIONS. Birgel, S. H. (Southwest Res. Inst., San Antonio, Tex.).

See CR 0057, Volume I(2), for description of this research. (Renewed 7/74-6/75)

Supporting Agency:U. S. Dep. Def., Air Force

0132 USE THE DEVELOPED DNA MODEL SYSTEM TO DETECT PHYSICAL AND BIOLOGICAL (GENETIC) CHANGES INDUCED BY NON-IONIZING RADIATION EXPOSURE. Blackman, C. F. (Natl. Environ. Res. Cent., Durham, N. C.).

Alterations in chemical/physical properties of a selected genome (bacteriophage phi-x174) will be used to monitor the biological significance of MW induced genetic damage. Attention will be given to thermal/nonthermal effects and dose response relationships. (7/74-6/75)

Supporting Agency:EPA, Off. Res. Dev.

0133 EFFECTS OF ELECTROMAGNETIC FIELDS ON GENETIC PHENOMENA. Braver, G. (Univ. Oklahoma, Norman).

A renewal of the contract reported in CR 0015, Volume I(2), is being conducted to study the effects of athermal MW radiation and homogeneous and heterogeneous ES and magnetic fields on mutation and on chromosome behavior as measured by meiotic exchange frequencies and rates of nondisjunction. Biological effects of EMFs which do not produce heating, are being investigated. Studies are in the preliminary stages of attempting to determine the internal temperature of flies irradiated with MWs. The methods of attack on the internal problems include: (1) irradiating different numbers of flies in enclosed vials with MWs; (2) use of cholesteric liquid crystal mixtures which exhibit brilliant color changes over specified temperature ranges; and (3) use of IR thermographic techniques. These studies will contribute to the knowledge of the genetic effects of MW fields in X-brand as well as effects of strong ES and magnetic fields and finally yield some information on safe levels of exposure. (7/74-6/75)

Supporting Agency:EPA, Off. Res. Div.

0134 ACCELERATION OF FRACTURE HEALING BY ELECTRICAL FIELDS. Brighton, C. T.; Friedenberg, Z. B.; Black, J.; Korostoff, E.; Heppenstall, R. B. (Sch. Med., Univ. Pennsylvania, Philadelphia).

The object of the proposed research is to continue investigating the effects of an applied electrical current and/or field on the acceleration of fracture healing in laboratory animals. The research is designed: (1) to determine the comparative effectiveness of direct constant and pulsed current, alternating current, ESPs, and magnetically induced electrical fields in producing osteogenesis and in accelerating fracture healing in laboratory animals;

and (2) to determine the site and mechanism of action of electrical stimulation on medullary canal cells and on fracture callus cells. Methods to be used include point-counting analysis of histologic sections for new bone formation produced in an intact medullary canal around a cathode in response to various parameters of current, voltage, ES, and EM fields; mechanical testing for maximum resistance to bending of healing fractures in laboratory animals; point-counting analysis of electron micrographs of fracture callus cells in order to quantitate changes in cytoplasmic components; electron microscopy combined with histochemistry of fracture callus cells in order to detect changes in cell membrane surface charges; and determination of changes in tissue pO_2 , O_2 consumption, and pCO_2 by means of a tissue tonometer system. (9/74-8/75)

Supporting Agency:HEW, Public Health Serv.

0135 EMP EFFECTS ON CARDIAC PACEMAKERS. Brunhart, G.; Martz, J. R. (Armed Forces Radiobiol. Res. Inst., Bethesda, Md.).

See CR 0043, Volume I(2), for description of this research. (Renewed 7/74-6/75)

Supporting Agency:U. S. Dep. Def., Def. Nucl. Agency

0136 EFFECTS OF LOW INTENSITY MICROWAVE RADIATION ON MAMMALIAN SERUM PROTEINS. Cleary, S. F.; Berry, E. R. (Virginia Commonw. Univ., Richmond).

This project investigates the molecular effects of low intensity MW radiation on mammalian serum proteins to support the effort to define the military medical problems associated with exposure to MW hazards. It is relevant to the mission of the Army Medical Department in maintaining military forces in the field. This study will be conducted in three phases: (1) broad survey of *in vivo* effects of MW radiation on bio-micromolecules in the rabbit and monkey to detect specific sensitivities to nonthermal levels of radiation; (2) identification, isolation, and characterization of the MW-sensitive molecular species; (3) detailed *in vitro* experimental and theoretical investigation of sensitive molecules to attempt to determine the basic mechanism(s) of interaction with the EMP. (7/74-6.75)

Supporting Agency:U. S. Dep. Def., Army

0137 INVESTIGATION OF RF INDUCED BIOCHEMICAL CHANGES. Conover, D. (Public Health Serv. Cent. Dis. Control, Cincinnati, Ohio).

The utility of biochemical changes as indicators of RF induced biological damage will be investigated in experimental animals. These biochemical changes will be monitored by observing the relative concen-

trations of selected ions to identify the most sensitive indices of RF biological damage and to study the mechanisms involved in these biochemical changes. Based on findings from the industrial surveys and available RF biological effects data, a RF biological effects research program will be developed to determine the adequacy of the OSHA MW/RF standard from 10 to 40 MHz. Dielectric materials will be developed which have electric and thermal properties which are similar to human tissues so that phantom simulations of humans may be constructed. (7/74-6/75)

Supporting Agency:HEW, Public Health Serv.

0138 INVESTIGATION OF RADIOFREQUENCY RADIATION IN INDUSTRY. Conover, D. (Public Health Serv. Cent. Dis. Control, Cincinnati, Ohio).

Magnetic and electric field probes will be utilized to measure the magnitudes of these fields. The survey will include various types of industrial RF power sources operating at 13.56, 27.12, and 40.68 MHz. Power sources will be carefully surveyed to determine the potential for hazardous occupational exposures. A RF irradiation facility will be developed for the Physical Agents Branch of HEW by the EM Fields and Antennas Section, NBS, Boulder, Colorado, to evaluate probes and to expose phantom simulation of human beings. The facility will be capable of generating RF fields at 13.56, 27.12, and 40.68 MHz. (7/74-6/75)

Supporting Agency:HEW, Public Health Serv.

0139 PERFORMANCE IN NON-HUMAN PRIMATES AS INFLUENCED BY LOW FREQUENCY ELECTROMAGNETIC FIELDS. deLorge, J. O.; Grissett, J. D. (U. S. Navy Aerosp. Med. Res. Lab., Pensacola, Fla.).

See Cr 0006, Volume I(1), for description of this research. (Renewed 7/74-6/75)

Supporting Agency:U. S. Dep. Def., Navy

0140 TO DESIGN AND STUDY THE EFFECTS OF BIOMEDICAL SYSTEMS ON ANIMALS. Dracy, A. E.; Sander, D. E.; Bush, L. F. (Agric. Exp. Stn., South Dakota State Univ., Brookings).

This project is to design and test the validity of a volume conduction system for measuring body temperature continuously and to study the effects of MWs for partial and complete sterilization of farm animals. It will also design and test a unit which will have an exciting effect on rats and mice and will be used to help keep rodents out of buildings. Circuitry built during the school year will be used and the water stability problems as they effect the operation of the circuit will be improved. The

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project will place implants to monitor temperatures of the internal organs of the animal, and will build a MW cavity and obtain equipment to irradiate the testicles of a sheep safely. The subject will be irradiated and the amount of sterility will be tested as a function of radiation power and time of exposure. A power supply will be designed and built from existing sources and the effectiveness of the sound source will be tested on the eradication of rats and mice. (7/74-6/75)

Supporting Agency:South Dakota State Gov.

- 0141 EFFECT OF PHYSICAL STIMULI ON INSECTS.
Earp, U. F.; Perumpral, J. V. (Sch. Agric.,
Virginia Polytech. Inst., Blacksburg).

The objective of this project is to determine the response to physical stimuli, especially EMF energy, of certain insects of economic importance in Virginia, and to determine the feasibility of the physical stimuli as an attractant or repellent, or as a population suppressant, of insects. Insect behavior in two different fields in the zero frequency range, namely, the magnetic and the ES fields will be studied. Experiments will be conducted to determine the effect of EMFs, including flight chambers for orientation behavior, homogeneous fields for egg laying and hatchability, and CO₂ production monitoring for insect activity. Experiments to study the effects of low intensity magnetic and ES fields are in progress. The data to date indicate the following: magnetic fields of two strengths (60 and 120 gauss) had no effect on the orientational behavior of cabbage loopers of either sex. Continuous exposure of cabbage looper eggs to magnetic fields of 10, 48, 180, and 2000 gauss had no effect on hatchability. The effects of magnetic fields on other looper activities are being evaluated. An ES field of about 200 V/cm apparently affects the orientation behavior of house flies. These data are considered desirable to evaluate their possible use for insect control. (7/74-6/75)

Supporting Agency:Virginia State Gov.

- 0142 RADIOFREQUENCY HEAT FOR CANCER THERAPY.
Edwards, W. S.; Doss, J. D.; Weiss, G. K.;
Key, C. (Sch. Med., Univ. New Mexico, Albuquerque).

See CR 0047, Volume I(2), for description of this research. (Renewed 1/75-12/75)

Supporting Agency:HEW, Public Health Serv.

- 0143 MICROWAVES - ENVIRONMENTAL FACTOR - A
MOLECULAR VIEW. Eisenbud, M.; Rabinowitz,
J.; Mumford, W. (New York Univ. Sch. Med., New York).

The purpose of this project is to investigate the biological effects of MW radiation on the molecular level. The mechanisms for the basic interactions

between MW radiation and biological molecules, along with possible functional implications have been considered. A model for the direct interference of MW radiation with biomolecular functions that are dependent on the internal three dimensional structure of the absorbing molecule has been developed. Specific systems where MW effects suggest the possible operation of this mechanism on the molecular level are being studied. In addition, the effect of MW radiation on the uptake of ascorbic acid by rabbit lenses and the effect on the activity of acetylcholinesterase both in its pure form and in whole blood are being studied. Future plans include a look at the effect of MW radiation on the uptake of known actively transported compounds in rabbit lens and a look at the effects of MW radiation on cation transport in red blood cells and possible local state changes in membranes. (9/74-8/75)

Supporting Agency:HEW, Public Health Serv.

- 0144 CYTOGENETIC EFFECTS OF MICROWAVE RADIATION
ON CHINESE HAMSTERS (VARIABLE POWER DEN-
SITY). Everts, J. M. (Natl. Environ. Res. Cent.,
Durham, N. C.).

See CR 0033, Volume I(1), for description of this research. (Renewed 7/74-6/75)

Supporting Agency:EPA, Off. Res. Dev.

- 0145 CYTOGENETIC EFFECTS OF MICROWAVE RADIATION
ON TISSUE CULTURE. Everts, J. M. (Natl.
Environ. Res. Cent., Durham, N. C.).

See CR 0026, Volume I(1), for description of this research. (Renewed 7/74-6/75)

Supporting Agency:EPA, Off. Res. Dev.

- 0146 GENETIC EFFECTS OF MICROWAVE RADIATION ON
CHINESE HAMSTERS. Everts, J. M. (Natl.
Environ. Res. Cent., Durham, N. C.).

See CR 0014, Volume I(1), for description of this research. (Renewed 7/74-6/75)

Supporting Agency:EPA, Off. Res. Dev.

- 0147 CARDIAC OUTPUT MEASUREMENT BY MEANS OF
RF ATTENUATION MEASUREMENT. Frazer, J. W.
(U. S. Air Force Sch. Aerosp. Med., Brooks Air
Force Base, San Antonio, Tex.).

See CR 0069, Volume I(2), for description of this research. (Renewed 7/74-6/75)

Supporting Agency:U. S. Dep. Def., Air Force

0148 BEHAVIORAL AND BIOLOGICAL EFFECTS OF RESONANT ELECTROMAGNETIC POWER ABSORPTION IN RATS. Gandhi, O. P.; Johnson, C. C. (Sch. Eng., Univ. Utah, Salt Lake City).

See CR 0080, Volume I(3), for description of this research. (Renewed 7/74-6/75)

Supporting Agency:U. S. Dep. Def., Army

0149 SCIENTIFIC AND TECHNICAL PROGRAMS FOR MONITORING OF ENVIRONMENTAL RADIATION LEVELS AND INVESTIGATION OF BIOLOGICAL EFFECTS. Grove, H. M. (U. S. Army, Walter Reed Army Inst. Res., Washington, D. C.).

See CR 0028, Volume I(1), for description of this research. (Renewed 7/74-6/75)

Supporting Agency:EPA, Off. Res. Dev.

0150 DEVELOP AND VALIDATE EQUATIONS TO ALLOW EXTRAPOLATION OF RF ANIMAL DATA TO MAN FOR HAZARD ASSESSMENT PURPOSES. Guy, A. W. (Sch. Med., Univ. Washington, Seattle).

See CR 0052, Volume I(2), for description of this research. (Renewed 7/74-6/75)

Supporting Agency:U. S. Dep. Def., Air Force

0151 BIOLOGICALLY IMPORTANT RF POWER ABSORPTION MEASUREMENTS FOR SAFETY CRITERIA. Howell, W. A. (Block Eng. Inc., Cambridge, Mass.).

See CR 0054, Volume I(2), for description of this research. (Renewed 7/74-6/75)

Supporting Agency:U. S. Dep. Def., Air Force

0152 UHF BAND RADIOFREQUENCY RADIATION FOR CARDIAC PACEMAKER EMI STUDIES. Toler, J. C. (Georgia Inst. Technol., Atlanta).

See CR 0081, Volume I(3), for description of this research. (Renewed 7/74-6/75)

Supporting Agency:U. S. Dep. Def., Air Force

0153 HATCHABILITY OF CHICKEN AND TURKEY EGGS. Krueger, W. F. (Agric. Exp. Stn., Texas A & M Univ., College Station).

Incubational and preincubational factors influencing hatchability of chicken and turkey eggs under south-

ern climatic conditions will be investigated and evaluated. Causes of egg spoilage during incubation will be determined and methods of preventing this condition will be established. Incubational and preincubational factors necessary for optimum embryonic development with seasons will be correlated. The project will investigate interrelationships between hatchability and other genetic characteristics of economic importance under varying incubational and pre-incubational conditions. Pedigree hatching eggs will be characterized after treatment by making various chemical and weight measurements of the shell, albumin and yolk of eggs one week each month. Similar eggs from the same pedigreed hens will be incubated usually under three incubation conditions to determine treatment effects. Egg spoilage during incubation and public health pressures are problems of considerable importance to the hatchery industry. Studies are in progress to determine methods of efficiently preventing spoilage of hatching eggs and of sanitizing hatching eggs prior to and during incubation. Genetic differences in the various egg characteristics must eventually be related to other physiological characteristics of the bird to avoid genetic antagonisms. Maintaining records on a pedigree basis allows one to study these potential antagonisms. Continuous exposure of breeder males and females to low level EM fields had no significant effect on fertility, hatchability, chick quality or sex ratio. Birds lived in these environments for four months. (7/74-6/75)

Supporting Agency:Texas State Gov.

0154 EPIDEMIOLOGICAL FIELD STUDY OF ATHERMAL NON-IONIZING ELF ELECTROMAGNETIC RADIATION EFFECTS. Krumpe, P. E. (U. S. Navy Med. Res. Unit #4, Waukegan, Ill.).

See CR 0002, Volume I(1), for description of this research. (Renewed 7/74-6/75)

Supporting Agency:U. S. Dep. Def., Navy

0155 ELECTROMAGNETIC FIELD ORIENTATION. McCleave, J. D.; Albert, E. H. (Sch. Arts, Univ. Maine, Orono).

The proposed research is to examine the hypothesis that migratory fish can orient to the earth's magnetic field and to the electric fields generated by ocean currents. The specific objectives, using American eels and Atlantic salmon, are to determine: (1) a conditioned behavioral d.c. electric current sensitivity threshold; (2) if the fish can discriminate the polarity of a weak d.c. electric field; (3) if the orientation of a weak electric or magnetic field can influence the fishes' body orientation; and (4) if electroreceptors are present in the integument of eels. (9/74-8/75)

Supporting Agency:HEW, Public Health Serv.

CURRENT RESEARCH

0156 ELECTRICAL AND ACOUSTIC PROPERTIES OF BIOLOGIC MATERIALS. Schwan, H. P.; Takashima, S. (Sch. Eng., Univ. Pennsylvania, Philadelphia).

See CR abstract, Volume I(3), p. 51, for description of this research. (Renewed 10/74-9/75)

Supporting Agency:HEW, Public Health Serv.

0157 BIOLOGICAL EFFECTS OF PULSED ELECTROMAGNETIC FIELDS. Skidmore, W.; Brunhart, G. (Armed Forces Radiobiol. Res. Inst., Bethesda, Md.).

See CR 0041, Volume I(2), for description of this research. (Renewed 7/74-6/75)

Supporting Agency:U. S. Dep. Def., Def. Nucl. Agency

0158 FURTHER STUDIES ON THE HAZARDS OF MICRO-WAVE IRRADIATION AS INDICATED BY CNS NEUROTRANSMITTERS. Snyder, S. H.; Sharp, J. C. (Johns Hopkins Univ. Sch. Med., Baltimore, Md.).

This project is designed to investigate the nature and extent of hazards to the CNS and its function due to MW and RF emanations from military devices and equipment such as radar and communications gear. Chemical determination of changes in CNS levels and turnover rates of important neurotransmitters (5-hydroxytryptamine and norepinephrine) involved in thermoregulation as well as levels of consciousness and behavioral excitation will be studied. (7/74-6/75)

Supporting Agency:U. S. Dep. Def., Army

0159 LABILE METABOLITES, TRANSMITTERS IN THE HEART CYCLE. Stavinoha, W. B.; Medina, M. A.; Modak, A. T.; Deam, A. P.; O'Brien, L. J. (Univ. Texas Sch. Med., San Antonio).

MW radiation will be used to inactivate in 130 msec the enzymes in the isolated perfused turtle heart. ECG and pressure records will enable us to know precisely the moment of inactivation within the cardiac cycle. The cardiac cycle will be stopped at 6 different intervals and the following measurements will be done in the left auricle, right auricle and ventricle: acetylcholine, choline, nor-epinephrine, cyclic AMP, cyclic GMP, the high energy phosphates, ADP, ATP, AMP, phosphocreatine, lactate, pyruvate, and the ions calcium and magnesium. This should provide extensive new information about the metabolism and regulation of the heart beat. (9/74-8/75)

Supporting Agency:HEW, Public Health Serv.

0160 STUDY OF BRAIN METABOLISM THROUGH MICRO-WAVE HEATING. Stavinoha, W. B.; Medina, M. A. (Sch. Med., Univ. Texas, San Antonio).

See CR 0055, Volume I(2), for description of this research. (Renewed 2/75-1/76)

Supporting Agency:HEW, Public Health Serv.

0161 RADIOFREQUENCY ELECTROMAGNETIC ENVIRONMENT SIMULATION AND MEASUREMENT. Allen, S. J. (U. S. Air Force Sch. Aerosp. Med., San Antonio, Tex.).

The objective of this work unit is to develop the RF radiation simulators and instrumentation required to reproduce Air Force (AF) operational RF environments in the laboratory to support bioeffects studies. The results of such studies will continue to provide the basis for modifying the personnel exposure criteria for AF RF operations. Instrumentation will be developed to measure E- and H-fields independently and simultaneously at frequencies up to 1 GHz. The instrumentation and theory which will allow complex dielectric measurement in fields of 1 to 10 GHz using six-port theory will be developed. An orthogonal dipole instrument which will measure peak energy density in pulsed RF environments will be developed. A study to compare RF field measuring techniques will be performed in the USAFSAM exposure chambers by USAFSAM/RAP and Keesler AFB personnel. Power absorption studies in the 10-50 MHz region, setup of multiple frequency fields for bioeffects studies and a study to determine potential problems in phased array systems will be completed.

Supporting Agency:U. S. Dep. Def., Air Force

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