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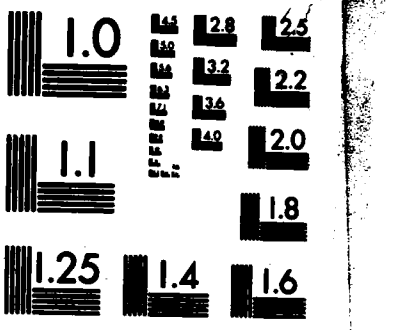

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The primary goal of the Symposium was to bring together engineers, physical scientists, physiologists, and psychologists to discuss how nonionizing radiation deposits thermalizing energy in biological tissues and the means by which this energy may be detected and effectively dealt with by the conscious organism. Much is known of the mechanisms by which endotherms achieve and maintain a characteristic stable internal body temperature in the face of environmental and internal thermal stresses. Nonionizing radio-frequency radiation provides a unique thermal challenge to deep as well as

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peripheral tissues that must be dealt with by these same mechanisms. Over the past several years, research into the biological effects of microwave exposure has advanced considerably; research emphasis has shifted from high intensity to low intensity exposure as scientists probe more and more subtle biological effects. With this shift in emphasis has come the realization that a body temperature increase in an experimental animal exposed to microwaves implies a breakdown of thermoregulatory mechanisms. On the other hand, low intensity exposures (previously dubbed "non-thermal") usually initiate immediate and efficient thermoregulatory processes that ensure the constancy of the internal body temperature. A total of 80 registrants for the Symposium included the 25 speakers and session chairmen who were invited to participate. Symposium participants and other guests were afforded an opportunity to visit several laboratories where research is conducted into thermoregulatory processes in men and animals as well as into the biological consequences of microwave exposure. The formal Symposium proceedings comprised morning and afternoon sessions on each day, during which the invited scientists presented 20-minute talks on topics suggested by the Symposium organizer. Each talk was followed by a 10-minute period for open discussion. Each afternoon session concluded with a panel discussion followed by an open discussion.

MICROWAVES AND THERMOREGULATION: A SYMPOSIUM

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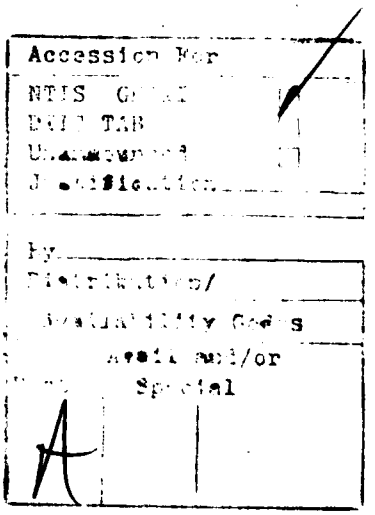
February, 1983



FINAL REPORT

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JUNE 30, 1981 - DECEMBER 31, 1982

PREPARED FOR

DEPARTMENT OF THE AIR FORCE

AIR FORCE OFFICE OF SCIENTIFIC RESEARCH (AFSC)

BOLLING AIR FORCE BASE, D.C. 20332

On October 26 - 27, 1981, a Symposium on Microwaves and Thermoregulation was held in New Haven, Connecticut under the auspices of the John B. Pierce Foundation of Connecticut, Inc. Funded by the Tri-Service Electromagnetic Radiation Panel, TERP, this Symposium featured two days of invited talks and panel discussions.

The primary goal of the Symposium was to bring together engineers, physical scientists, physiologists, and psychologists to discuss how nonionizing radiation deposits thermalizing energy in biological tissues and the means by which this energy may be detected and effectively dealt with by the conscious organism. Much is known of the mechanisms by which endotherms achieve and maintain a characteristic stable internal body temperature in the face of environmental and internal thermal stresses. Nonionizing radiofrequency radiation provides a unique thermal challenge to deep as well as peripheral tissues that must be dealt with by these same mechanisms.

Over the past several years, research into the biological effects of microwave exposure has advanced considerably; research emphasis has shifted from high intensity to low intensity exposure as scientists probe more and more subtle biological effects. With this shift in emphasis has come the realization that a body temperature increase in an experimental animal exposed to microwaves implies a breakdown of thermoregulatory mechanisms. On the other hand, low intensity exposures (previously dubbed "non-thermal") usually initiate immediate and efficient thermoregulatory processes that ensure the constancy of the internal body temperature.

The John B. Pierce Foundation was founded in 1924 to "...promote research, educational, technical, or scientific work in the general fields of heating, ventilation, and sanitation, for the increase of knowledge to the end that the general hygiene and comfort of human beings and their habitations may be advanced." Many staff members, world authorities on thermal sensation, thermal comfort, environmental physiology, exercise physiology, febrile states, cardiovascular adjustments, behavioral mechanisms, and models of human thermoregulation participated in the Symposium program. Their awareness of the special thermoregulatory problems posed by microwave exposure was greatly enhanced through interaction during the Symposium with the participating biologists, psychologists, biophysicists, and electrical engineers who are experts in the physical basis and biological effects of nonionizing radiofrequency radiation. The resulting exchange of ideas promoted an understanding of the many problems both disciplines share in common and the scientific benefits of future collaboration. Both the formal program and coordinated social events were designed to maximize scientific interchange not only among the participants but with members of the audience as well.

A total of 80 registrants for the Symposium included the 25 speakers and session chairmen who were invited to participate. The sessions were held in the Mary S. Harkness Auditorium, Sterling Hall of Medicine, on the campus of the Yale University School of Medicine. This building is located 1½ blocks from the John B. Pierce Foundation Laboratory. The Symposium events began on Sunday afternoon, October 25, with an open house at the Pierce Foundation. This event afforded the Symposium participants and other guests an opportunity to visit several laboratories where research is conducted into thermoregulatory processes in men and animals as well as into the biological consequences of microwave exposure. The open house was followed by an informal social hour at the Park Plaza Hotel and a buffet supper for participants and other special guests.

The formal Symposium proceedings comprised morning and afternoon sessions on each day, during which the invited scientists presented 20-minute talks on topics suggested by the Symposium organizer. Each talk was followed by a 10-minute period for open discussion. Each afternoon session concluded with a panel discussion followed by an open discussion. After the afternoon session on the first day, a reception and banquet were held in the Yale University dining hall (President's Room); nearly 100 people attended this enjoyable event and were entertained royally by the banquet speaker, Prof. Charles Süsskind. A special guest of honor at the banquet and during the sessions of the second day, was Mrs. Dorothea F. Sacher, widow of George Sacher to whom tribute was paid in the panel discussion on Tuesday afternoon.

Outline of Program

The formal program, including the speakers and their topics, is set down below. Two invited participants were unable to take part at the last minute. Arthur W. Guy's paper was presented by his close colleague Chung-Kwang Chou, who also participated in the panel discussion on Monday afternoon. Richard D. Phillips was prevented from attending; John T. Stitt served as Chairman of Session VI and Richard H. Lovely contributed to the Tuesday Panel Discussion in his stead. Joseph C. Stevens was prevented from participating by sudden illness. His paper was read by Lawrence E. Marks and Don R. Justesen filled in for him as a panelist on Monday afternoon.

PROGRAM

MONDAY, OCTOBER 26, 1981
MARY S. HARKNESS AUDITORIUM

0800 **REGISTRATION**

0830 **WELCOME AND OPENING REMARKS**
Arthur B. DuBois, Director, John B. Pierce Foundation Laboratory
Charles K. Bockelman, Deputy Provost, Professor of Physics, Yale University
Eleanor R. Adair, Symposium Organizer

SESSION I

MICROWAVES AND THE THERMAL ENVIRONMENT

Chair: James D. Hardy
John B. Pierce Foundation
New Haven, CT

0845 *Historical introduction.* Herman P. Schwan, Department of Electrical Engineering, University of Pennsylvania, Philadelphia, PA.

0915 *Characterizing the thermal environment.* Larry Berglund, John B. Pierce Foundation, and Yale University, New Haven, CT.

0945 *The microwave stimulus.* John Osepchuck, Raytheon Research Division, Waltham, MA.

1015 **COFFEE BREAK**

SESSION II

ENERGY DEPOSITION IN BIOLOGICAL TARGETS

Chair: A. Pharo Gagge
John B. Pierce Foundation
New Haven, CT

1030 *Electromagnetic heating for therapy: A critical evaluation.* Arthur W. Guy, Bioelectromagnetics Research Laboratory, University of Washington School of Medicine, Seattle, WA.

1100 *In-vivo temperature measurements during whole-body exposure of Macaca species to resonant and non-resonant frequencies.* Jerome H. Krupp, United States Air Force School of Aerospace Medicine, Brooks AFB, TX.

1130 *Infrared radiation and human thermal comfort.* Lawrence E. Marks, John B. Pierce Foundation and Yale University, New Haven, CT.

1200 **LUNCHEON BREAK**

SESSION III

THERMOREGULATION AND THERMAL SENSATION

Chair: Eleanor R. Adair
John B. Pierce Foundation
New Haven, CT

1330 *Body temperature regulation during euthermia and hyperthermia.* Steven Shimada and John T. Stitt, John B. Pierce Foundation and Yale University, New Haven, CT.

1400 *Characteristics of central controlling mechanisms.* H. Craig Heller, Department of Biological Sciences, Stanford University, Stanford, CA.

1430 *Thermal sensation: Infrared and microwaves.* Joseph C. Stevens, John B. Pierce Foundation and Yale University, New Haven, CT.

1500 *Sensory dynamics of microwave irradiation: A comparison of human and infra-human data.* Don R. Justesen, United States Veterans Administration Medical Center, Kansas City, MO.

1530 REFRESHMENT BREAK

SESSION IV

PANEL DISCUSSION: SENSATION, SUBTLETIES AND STANDARDS

Chair: Michel Cabanac
Université Laval
Quebec, P.Q. Canada

1545-1700 PARTICIPANTS: John Osepchuck
Jan A. J. Stolwijk
Arthur W. Guy
Joseph C. Stevens.

1800 RECEPTION — Woolsey Hall

1900 SYMPOSIUM BANQUET — The President's Room

Beyond Thermoregulation. Charles Süsskind, College of Engineering, University of California, Berkeley, CA.

TUESDAY, OCTOBER 27, 1981
MARY S. HARKNESS AUDITORIUM

SESSION V

AUTONOMIC RESPONSE SYSTEMS

Chair: Richard D. Phillips
Battelle Northwest Laboratories
Richland, WA

0830 *Circulatory and sweating responses during exercise and heat stress.* C. Bruce Wenger, John B. Pierce Foundation and Yale University, New Haven, CT.

0900 *Human heat acclimatization.* Ralph F. Goldman, United States Army Research Institute of Environmental Medicine, Natick, MA.

0930 *Thermoregulation during intensive microwave exposure.* Sol M. Michaelson, Department of Radiation Biology and Biophysics, University of Rochester, Rochester, NY.

1000 *Evaluation of thermoregulatory response to microwave power deposition.* Jan A. J. Stolwijk, John B. Pierce Foundation and Yale University, New Haven, CT.

1030 COFFEE BREAK

SESSION VI

THERMOREGULATORY BEHAVIOR

Chair: John O. deLorge
Naval Aerospace Medical Research Laboratory
Pensacola, FL

1045 *Behavioral responses to the thermal environment.* Michel Cabanac, Department of Physiology, School of Medicine, Université Laval, Quebec.

1115 *Changes in thermoregulatory behavior during microwave irradiation.* Eleanor R. Adair, John B. Pierce Foundation and Yale University, New Haven, CT.

1145 LUNCHEON BREAK

SESSION VII

MICROWAVE EXPOSURE: SPECIAL CASES

Chair: Jerome H. Krupp
USAF School of Aerospace Medicine
Brooks AFB, TX

1315 *The thermal basis for disruption of operant behavior by microwaves in three animal species.* John O. deLorge, Naval Aerospace Medical Research Laboratory, Pensacola, FL.

1345 *Subtle consequences of exposure to weak microwave fields: Are there non-thermal effects?* Richard H. Lovely, Biology Department, Battelle Northwest Laboratories, Richland, WA.

1415 *Detection of nonionizing radiation-induced whole body heating following chemical impairment of thermoregulation.* Ralph J. Smialowicz, United States Environmental Protection Agency, Research Triangle Park, NC.

1445 *Influence of the circadian rhythm of body temperature on the physiological response to microwaves: Day vs night exposure.* W. Gregory Lotz, Naval Aerospace Medical Research Laboratory, Pensacola, FL.

1515 REFRESHMENT BREAK

SESSION VIII

PANEL DISCUSSION: METABOLISM, LONGEVITY AND MICROWAVES

A MEMORIAL TRIBUTE TO GEORGE SACHER

Chair: Charles Süsskind
University of California
Berkeley, CA

1530-1700 PARTICIPANTS: Don R. Justesen
Richard D. Phillips
Sol M. Michaelson

1700 ADJOURN

Summary of Scientific Papers

Individual sessions were organized around broad subject topics as indicated in the program outlined above. Session I, Microwaves and the Thermal Environment, served as an introduction to the major theme of the Symposium. Herman Schwan, the first speaker, had collaborated with James D. Hardy at the University of Pennsylvania in the 1950's on the pioneering efforts to measure sensations derived from the exposure of human subjects to microwaves. From his vantage point as the Dean of research in this area, Prof. Schwan presented a capsule history of the two subject disciplines, microwave effects and thermoregulation. He emphasized the construction and refinement of simulation models of human thermoregulation on the one hand and of the deposition of microwave energy in humans on the other hand. Recent efforts in his laboratory have involved preliminary attempts to combine these two kinds of models, an effort he characterized as extremely fruitful.

Larry Berglund, a talented environmental engineer from the Pierce Foundation, outlined the standard methods of describing man's exchange of thermal energy with his environment. He offered the concepts of operative temperature and mean radiant temperature as useful simplifications of the thermal environment's potential for heat transfer. He then showed that the fate of energy deposited in the body by microwaves could be characterized using the same traditional methods.

The tutorial presented by John Osepchuk included the basic physical principles involved in the generation, propagation, and measurement of radiofrequency electromagnetic energy. He emphasized the differences between microwaves and the infrared radiation that is more familiar to thermal biologists. He explained some typical microwave exposure systems and tried to point out many of the technical pitfalls inherent therein that might not be obvious to biologists new to the field. He concluded with a review of some practical aspects involving sensations and exposure artifacts gleaned from his wide experience.

Session II, Energy Deposition in Biological Targets, contained three presentations dealing with the fate of radiofrequency or infrared energy deposited in the body. Arthur W. Guy's paper, read by C.-K. Chou, reviewed the biophysics of tissue heating with radiofrequency electromagnetic waves and discussed the methods of quantifying the energy absorption and associated temperature increases at different depths within the body tissues. Special emphasis was placed on innovative methods currently used in clinics for producing heat in deep tissues, particularly microwave diathermy, which are based on fundamental dosimetric concepts. These clinical treatments are useful as adjuncts to effective cancer treatment.

Experiments to measure heating in deep tissues, to verify or refute temperature increments predicted by dosimetric theory, were described by Jerome H. Krupp. A non-perturbing temperature probe measured temperature changes in regions of high energy deposition (e.g. wrist, thigh, ankle, etc.) of rhesus monkeys exposed to 219 MHz planewaves. No experimental evidence for localized regions of high temperature rise was found, suggesting that predictions of such "hot spots" by mathematical models fail to account for greatly increased blood flow in these body regions during RFR exposure.

Lawrence E. Marks described the physical characteristics of infrared radiation and it's absorption by the skin. Since the peripheral thermodetectors reside within the first mm of the skin surface, they are easily stimulated by infrared radiation, giving rise to sensations of warmth and thermal comfort or discomfort. These sensations motivate men and animals to engage in behavioral activities that modify the thermal energy exchange with the environment. Some classic measurements of thermal sensation, pleasantness, and comfort/discomfort were described as these judgments are influenced by environmental temperature and humidity, and changes in air movement. Due to circumstances beyond his control, Mr. Marks was unable to prepare a chapter on this material for the Proceedings volume (see below). One of his Pierce Laboratory colleagues, Richard R. Gonzalez, graciously volunteered to assume this task.

Session III on Thermoregulation and Thermal Sensation was held on Monday afternoon. Two tutorials concerning the fundamentals of physiological thermoregulatory mechanisms and their neurological bases were followed by a paper on classical measurements of thermal sensation in human subjects. The last paper described our current knowledge of thermal sensations derived from radiofrequency radiation in both men and animals. Steven Shimada discussed the heat balance equation (conservation of energy) in terms of heat production and the avenues of heat exchange between the organism and the environment. The neural substrate serving thermoregulation was described together with its mode of action during environmental heat stress, exercise, and febrile disease. It is clear that no change in set point for the body temperature occurs during exercise and this will also be the case during absorption of radiofrequency electromagnetic radiation.

H. Craig Heller presented additional details on the central nervous system integrative mechanisms underlying many different thermoregulatory response changes. The differential roles of skin and deep body temperature were discussed in detail for several species with particular emphasis placed on the action of the hypothalamic thermoregulatory center. Hammel's model of the central controller was illustrated by data from several experiments. The contribution of behavioral thermoregulatory responses was evaluated. Adaptation processes involved in fever, circadian rhythms, arousal, torpidity, and broadband regulation were also described in detail.

The paper by Joseph Stevens presented the classical literature of thermal psychophysics as derived from the stimulation of human skin by infrared radiation. Our current knowledge of the influence of many physical variables was reviewed so as to help formulate a hypothetical program of similar experiments with microwaves. The major variables include intensity of stimulation, duration, areal extent, wavelength, and locus of stimulation on the body. Subjective judgments derived include not only absolute thresholds, but differential thresholds, latencies, magnitude estimations and comparative judgments.

Few experimental investigations have determined the characteristics of sensation aroused by microwave irradiation: we must rely heavily on the results of animal studies for our knowledge in this regard. Don R. Justesen discussed data from both human and animal studies that bear on a seeming paradox in the perception of microwave fields, namely, that low intensities give rise to threshold warmth sensation but high intensities seem not to be recognized as life-threatening, at least under certain circumstances. Additional experimental evidence indicated that careful training of animal subjects enhanced escape learning from near-lethal microwave fields such that normal thermoregulation was assured. These results have practical import for the technically naive worker in an industrial setting where high powered sources of HF, UHF, and VHF fields are present.

A panel discussion of the topic Sensation, Subleties and Standards concluded the afternoon sessions of the first day. The panel explored the characteristics of microwave sensations, the probable underlying temperature gradients in the exposed tissues, and whether such sensations should play a role in the setting of standards for exposure of the general population to radiofrequency fields. The role of familiarity with the source of radiant energy and the subjective assessment of risk or potential hazard was discussed. The old (1974) and new (1982) standards promulgated by ANSI were described together with the variables considered by the C-95 committee when proposing revisions of the standard. Some of the salient features of microwave sensation were described, including temporal fuzziness, fading, and persistence. All panelists agreed that more experimentation with human subjects was essential in order to evaluate the role of sensation in the total response to microwave exposure.

Following the Symposium banquet, Charles Susskind discoursed on the biological mechanisms that may be stimulated when organisms are exposed to radiofrequency fields at energy levels below those that produce heating of tissues. He began with a history of early work in the field of bioelectromagnetics, including that of Tesla and d'Arsonval. He then suggested a wide range of mechanisms that may be activated and, in the process, urged his audience to let their imaginations guide their scientific inquiry. Researchers should consider the possible benefits as well as the potential risks of exposure to nonionizing electromagnetic energy.

The two sessions held on the second morning of the Symposium were concerned with detailed knowledge of both autonomic thermo-

regulatory response systems and thermoregulatory behavior. Both systems were examined as they may be influenced by both conventional thermal stimuli and by internal heat generated by absorbed microwave energy.

Bruce Wenger discussed the major avenues of heat loss from the human body during heat stress: peripheral circulatory adjustments and sweating. These responses can be expected to play a major role in the elimination of body heat generated during microwave exposure. The roles of deep body temperature and skin temperature in the control of skin blood flow, venodilation, and sweating were described for the condition of passive heat stress as well as during exercise. Concomitant changes in cardiac filling and stroke volume occur, especially during exercise-induced hyperthermia, that should be investigated in humans exposed to radiofrequency fields.

Can man acclimate to microwave irradiation? This question was discussed by Ralph Goldman in light of our knowledge of acclimatization processes to environmentally-produced heat loads. Exposure of humans to heat induces a variety of alterations including evolutionary changes, psychological/behavioral regulations, and physiological acclimation responses. Animal models are also useful to the study of acclimation processes. The extent to which this knowledge can be applied to the problems of adjustment to chronic microwave exposure is unkown but studies of similar design were suggested as a good place to gain insight.

Sol M. Michaelson described patterns of temperature response in conscious dogs exposed to high intensity pulsed microwave fields at different environmental temperatures. Such exposures are characterized by a triphasic change in body temperature: an initial rise gives way to a plateau phase after which an uncontrollable rise in temperature occurs and death ensues unless the animal is removed from the stressful conditions. The warmer the environment, the more rapidly the body temperature rise occurs in the presence of radiofrequency fields. Tolerance to high intensity microwaves develops across successive daily exposures and takes the form of smaller increments of body temperature to a specific microwave power density as well as greater endurance to longer exposures. Hydration helps to prevent excessive temperature rise during long exposures.

The deposition of electromagnetic energy as heat in all of the human body, or in specific parts of it, is one of the specific conditions which lend themselves uniquely to a preliminary evaluation through simulation (mathematical) modeling. Jan Stolwijk described the characteristics of his model of the human thermoregulatory system. He then demonstrated how it could be used to predict the changes in thermoregulatory sweating and regulated temperatures of the brain, skin, and body core when specific amounts of electromagnetic energy were deposited in various body compartments. His major conclusion was that the amount of thermal averaging over all body tissues through the convective heat transfer via blood flow will result in the protection of individual tissues from overheating under such circumstances.

Attention was then turned to the importance of behavioral responses in the regulation of the body temperature. Michel Cabanac catalogued the natural behavior patterns exhibited by diverse species from unicellular organisms to man. He paid particular attention to thermoregulatory behavior as studied in the laboratory, notably the selection of a preferred microclimate within a thermal gradient and learned operant control of environmental temperature. He observed that when an organism is exposed to deeply-penetrating radiofrequency radiation, the resulting thermal sensations (upon which effective behavioral action depends) may be unfamiliar and thus lead to aberrant or ineffective behavioral responses.

The literature describing changes in thermoregulatory behavior in the presence of microwave fields was reviewed by Eleanor Adair. Two basic behavioral paradigms were described. The first involves instinctive or learned behavioral alterations that occur when a microwave field is suddenly introduced, disturbing thermal balance. The second involves the direct utilization of a microwave field as a source of heat to achieve thermal balance. In most experimental situations investigated so far, microwave exposure at moderate levels is compensated by appropriate behavioral adjustments so that no significant change occurs in the regulated internal body temperature. However, this research area is truly in its infancy -- much work remains to be done.

Session VII was devoted to the description of four special cases in which an interaction between microwave exposure and thermoregulatory processes in the exposed animal have been observed. Four scientists whose research efforts are widely recognized within the bioelectromagnetics community spoke about their work.

John deLorge described the thermal basis for the disruption of ongoing observing-response performance in three animal species, rats, squirrel monkeys, and rhesus monkeys. His data demonstrated that a well-controlled operant response was unassailable or immune to disruption by microwaves as long as the animal's body temperature did not rise at least 1 ^{o}C above its baseline level.

Richard Lovely discussed some "subtle consequences of exposure to weak microwave fields". He reported that microwave exposure (SAR= 2.0-3.2 W/kg) for 10 hr/night caused rats to reduce their total food intake relative to sham-exposed controls. He also described changes in neonatal and adult body mass that occurred in the progeny of female rats exposed to microwaves for 20 hr out of 24 through 19 days of gestation, but not in the progency of sham- or caged-control rats. These effects may be related to alterations in thermoregulatory capacity, specifically of metabolic heat production.

The detection of radiofrequency-induced whole body heating following the chemical impairment of thermoregulation was discussed

by Ralph Smialowicz. Lipopolysaccharide and endotoxin were used in rats, and 5-HT in mice, to produce hypothermia. This technique permitted the subsequent measurement of reliable increments in deep body temperature when the treated animals were exposed to 2450 MHz microwaves at a power density (1 mW/cm^2) heretofore considered to be nonthermogenic. Smialowicz urged more prudent assessment of claims for "nonthermal" biological effects in the presence of radio-frequency fields.

W. Gregory Lotz described experiments designed to compare the effects of identical microwave exposures, carried out at two different phases of the circadian cycle, on body temperature and on circulating cortisol levels in the rhesus monkey. Rectal temperature increases during 8-hr microwave exposures were virtually identical for both day and night even though sham and exposed absolute temperatures were substantially lower at night due to the normal circadian rhythm of body temperatures. However, the marked increase in circulating corsisol levels that were observed during day exposures to 38 mW/cm^2 were completely absent during the night exposures. This result may be simply related to the absolute level of body temperature, although more complex circadian influences cannot be ruled out.

The final session of the Symposium was a panel discussion conducted as a memorial to George Sacher, a scientist whose untimely death occurred in January, 1981. The topic, Metabolism, Longevity, and Microwaves, was one dear to George's heart and indeed the panel had originally been planned so that he could serve as session chairman. Unfortunately, this was not to be. However, during the session many of the Symposium participants expressed warm thoughts of their associations with Sacher, most notably Sol Michaelson, who spoke of their work together on effects of ionizing radiation, and Don Justesen who showed a videotape of Sacher delivering a lecture on his favorite topic, longevity. Justesen then described and elaborated upon Sacher's free-energy hypothesis of life span enhancement. He has set down this material formally in a contribution to the proceedings volume from this Symposium.

Proceedings Volume

During the first week of April, 1983, Academic Press, Inc. will publish Microwaves and Thermoregulation, edited by Eleanor R. Adair. This 485-page book contains 23 chapters authored by the participants of the Symposium, including a synopsis of the first panel discussion and the tribute to George Sacher written by Dr. Justesen. The front matter of the book contains a listing of all contributors and acknowledges with gratitude the support of the Symposium by TERP, the Tri-Service Electromagnetic Radiation Panel as administered by AFOSR. The book also contains a comprehensive subject index.


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