GENERAL DISCUSSION: SESSION II*

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DR. W. ROSS ADEY: I shall reply to the first question:† Has any attempt been made to produce effects by tapping the skull at critical frequencies?

I know of no work done by tapping the skull, but a great deal of work has been done on whole body vibration. I was involved in this during the early 1960s, when the vibration of man in the course of a space craft launch was a very important consideration in terms of his performance capabilities. The Air Force developed a very large human shaker with a frequency range from about 1 to 30 Hz., and in our studies we used monkeys. There was extremely strong driving of brain wave patterns in the monkey at frequencies between about 11 and 15 Hz. Certain diencephalic and midbrain structures (such as the nucleus centrum medianum) seemed particularly sensitive to that range of frequencies. It is apparently associated with a slight modification of consciousness, but nothing that would be associated with gross deterioration in perceptual or discriminative abilities. Calculations of coherence from cross-spectral analysis between electroencephalographic records and the shaker table indicated that the "driving" in the electroencephalogram did not appear to arise in movements of the brain in the vicinity of the electrodes.

Electroencephalographic activation by stimulation with light and sound has been extensively studied, and light has been universally used to activate the electroencephalogram, along with certain drugs. One can

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†Several written questions were submitted to the speakers by members of the audience.

produce many abnormalities and even epileptic attacks by appropriate frequencies of light stimulation. Auditory stimulation in general is not successful.

I do not think that 10 mW/cm.^{2}, which corresponds to an electric E gradient in air of about 150 V/m., is likely to produce direct, immediate effects on brain function. Indirectly, of course, as pointed out by Dr. Stephen Cleary, 10 mW/cm.^{2} in man at appropriate microwave frequencies may perceptibly increase body temperature. In turn, this would be expected to activate hypothalamic mechanisms controlling brain and body temperature and associated endocrine functions, including steroids. I would expect direct interactions to be of little consequence, but the indirect actions would need to be taken much more seriously.

DR. WILLIAM M. LEACH: The following written question has been submitted: One of the systems that has been used to study the mutagenic effects of ionizing radiation is the *Tradescantia stamen* hair system used by Bond and others at Brookhaven. Has this exquisitely sensitive system been used to test for mutagenic effects of microwaves and other nonionizing radiations? If so, what are the results?

With respect to the use of *Tradescantia* with microwave radiation, no. It was used a number of years ago with infrared radiation and that work was summarized in Swanson's book on cytology and cytogenetics.[1] I do not think that we have an equally sensitive system as far as the sensitivity of the *Tradescantia* system for microwaves at the present time. I do not believe the *Tradescantia* system would be as sensitive with microwave radiation as it is with ionizing, a problem of dosing the beast.

DR. LEONARD R. SOLON (New York City Department of Health): What is your view of the oncogenic potential of microwaves or radiofrequency in the light of chromosomal or genetic influences?

DR. LEACH: I have several answers to that one. I was brought up with three laws of biology, one of which was that which will give it to you will also cure you of it. And, taking that with a little modification, the apparent successes at the present time with microwaves as a moderating influence in the cure of cancer would suggest that microwaves may, indeed, have an influence in the induction of cancer.

The view of microwave radiation as a promoter, I think, is an area of research that has not been exploited, and the statement I just made about the oncogenic potential of microwaves would fall into an area which has not been explored, which is the second law: You have to see it to believe

it. We have no explicit evidence that microwave radiation can cause or influence in any direct way the production of cancer.

My third answer: Some cellular studies of microwave radiation indicate that the cells have for some time lost something called "control of mitotic activity." That gets dangerously close to our definition of cancer.

The fourth answer is, I do not know. I understand from very unofficial channels that all involved parties have signed a contract, so we may actually fund a study that will look at this question.

DR. DON JUSTESEN: Dr. Shils has asked my reaction to a paper recently reported in *Science* in which rats exposed to a microwave field at a power density of 1 mW/cm.^{2} showed increased behavioral sensitivity to a tranquilizer.[2]

Let me reiterate what Professors Cleary and Gandhi said today: Power density numbers, even those carefully and precisely obtained in measurements with the best instruments in the best of engineering hands, are highly variable with respect to specific biological thresholds—an observation I shall expand upon in my presentation on behavioral effects of radiofrequency radiation (see pp. 1058-78). To take just one example, that of the grand mal convulsion induced by intense heating of an animal in a radiofrequency field, the power density thresholds cited in the literature range over more than two orders of magnitude, from 3 to more than 300 mW/cm.^{2} Part of this wide range is because a power density number is a time rate. It is, with respect to a field incident on an animal, the rate at which radiofrequency energy flows through a given area of space as it impinges on the animal. With smaller quantities of incident energy per unit of time, more time is needed to deposit enough energy to elevate the animal's body temperature to the convulsive threshold. (For periods less than 15 minutes, the mass normalized quantity of absorbed energy required to convulse an animal is about 25 to 35 j./g. under standard biological and environmental conditions.) Another important factor is the quantity of incident energy that is scattered—not absorbed—by the animal target. All things held equal, a rat in a 2,450 MHz. microwave field will absorb about five times more energy per unit of body mass than will a human being in the same 2,450 MHz. field. In other words, larger organisms absorb less energy per unit of body mass in a microwave field. A third and related factor is resonance. At certain frequencies of radiofrequency radiation and at specific anatomical orientations of an animal in a field, the rate of

energy absorption by the entire body or by a part of the body such as the head will increase greatly.

Turning now to the report in *Science,* I note that the senior author, John Thomas of the Naval Medical Research Institute at Bethesda, Md., is an accomplished psychologist whose data on chlordiazepoxide are closely paralleled by other data he will shortly publish[3] on dextroamphetamine. He found that exposure to pulsed 2,450 MHz. microwaves at an average power density of 1 mW/cm^2. can roughly double the effectiveness of a given dose of either drug with respect to its effect on the rat's performance of an operant task.

Dr. Thomas reported provocative data that must, however, be qualified in terms of the factors mentioned above. First, the quantity of energy absorbed by his rats was about 200 $\mu W/g$. (whole-body) during 30-minute exposures. Second, because each animal was arrayed in a field in which the head can become electrically resonant, the brains of his animals may have been absorbing radiofrequency energy at the rate of 0.6 to 0.8 mW/g., the thermal product of which is not a trivial addition to the metabolic activity of the brain. Indeed, if dosimetric measurements were to confirm this augmented energy loading of the brain, I would be surprised if modulation of psychoactive compounds by a radiofrequency field did not take place. Finally, the factor of scaling dictates that an adult man in the same 2,450 MHz. field would require a much higher power density to result in equivalent rates of energy absorption per unit of mass.

Dr. Thomas' findings are not of too much concern for human beings so far as 2,450 MHz. energy is concerned, but raise a troublesome question for workers who operate powerful industrial radiofrequency devices at frequencies near those inducing resonant absorption in the human being. Dr. Om Gandhi's data on human models reveal that a worker standing on a conductive floor in a 30 MHz. field will absorb significant quantities of radiofrequency energy per unit of incident energy. Because fields near some industrial devices may effectively average several hundred $mW/cm.^2$ one can be legitimately concerned about excessive exposures, especially when the human operator may be taking medication.

Work to continue Dr. Thomas' studies is clearly needed. I would note in passing that his finding of field-induced augmentation of drug efficacy is reminiscent of findings that radiofrequency radiation (albeit at much higher intensities) can also augment the radiosensitivity of neoplasms. Always

one to see the constructive side of an issue, I wonder, too, whether field augmentation of drug efficacy would not otherwise prove useful in the clinic. Microwave potentiation of narcotics at lessened dosages, for which there is already strong if indirect evidence,[4] is one possibility.

DR. STEPHEN F. CLEARY: I have been asked at what level of exposure effects become nonreversible. To the best of my knowledge, the only nonreversible effects reported from microwave exposure are cataracts and convulsions or death due to hyperpyrexia. In any case, the dose at which convulsions are encountered is 25 j./g. The cataractogenesis experiments have dose thresholds that in general appear to involve exposures on the order of an hour or so at intensities of about 10 mW/cm.[2] The rest of the effects reported are generally reversible in the context of the experiments; these have, in general, involved acute or short term exposures. There is a very good possibility that some reversible effects might become nonreversible if the exposures were continued long enough, but this has not been adequately investigated at this point.

DR. NORMAN SIMON: Because this program is on biomedical effects and there has been so much discussion concerning cataracts, I note a possible evasion of the answer to the question the physicians are asked, namely, is microwave radiation cataractogenic for the human being and at what level of exposure or dose?

DR. RUSSELL L. CARPENTER: I think there is no reason to feel that the human species has a species immunity to the effects of microwave radiation. We have very little information concerning thresholds. I would have to say we do not know. However, we can speculate just so long as we do not overspeculate. As I said, from a single acute dose, unless it was an accident in which the subject could not get away, I doubt very much that there would be a cataract. Regarding cases in which there are repeated low dosages (and it would have to be quite low if the subject were to feel no warmth at all), I see no reason why there could not be a cataract as a result.

But when you look at the human histories, they are so incomplete. For example, an ophthalmologist sees a patient with a posterior subcapsular cataract. The fact that that patient may at some time have been exposed to microwave radiation does not, of itself, automatically constitute a cause-and-effect relation. But too often this assumption has been made. Suppose we see someone who develops a posterior subcapsular cataract; we cannot extrapolate right from the rabbit to the man. They react differently at

different frequencies. If we get a patient with a posterior subcapsular cataract and investigate his history, it is very difficult to reconstruct retrospectively the conditions of any microwave exposure. At the most it can be said that he was near some microwaves. How much? We do not know. How often? Don't know. How long a period of exposure? Well, that happened some while ago. The problem is an extremely difficult one.

There have been a number of cases reported in literature for human cataractogenesis from microwaves. Most of them have been reported by Dr. Zaret, who feels that the pathognomic character is a thickening of the posterior capsule, but he says that that is not an actual thickening but one that seems to be a thickening when you view it with a slit lamp. I have been collecting lenses from cases of alleged microwave cataract in humans. I have serially sectioned them. I am trying to find out whether the radiation cataract, the so-called "microwave cataract," has any unique characteristic or characteristics like another known type of cataract. The only thing I have yet been able to find is two cases which bear some of the characteristics of the ionizing radiation cataract, except that they developed more rapidly.

I have a case well documented in which we were able to reconstruct the conditions of exposure. It was a case of microwave diathermy applied because of strained neck muscles. The subject subsequently developed bilateral posterior subcapsular cataracts. We could eliminate any other possible etiology. There was no familial history. He had taken no corticosteroids. There had been no uveitis or diabetes. So you could say, "Aha, now there is a case of microwave cataract." But what do you do with the cases of idiopathic cataract? You cannot just ignore them. Fortunately, we were able to photograph the lenses. We obtained them after extraction. I have serially sectioned and studied them and they show balloon cells migrating under the posterior capsule. There appears to be no thickening of the posterior capsule. The microwave power density that we could measure, next to his right eye, was 22 mW/cm.^{2} and at his left eye, which developed a posterior subcapsular cataract, it was only 8 mW. I am puzzled by that case and I think perhaps I may be too rigorous. But I think we should be rigorous because if we are going to report cases of microwave cataract just because of a possible association with a microwave oven, that is not scientific. I know of one case where an ophthalmologist diagnosed microwave cataracts in a woman who owned a microwave oven. The fact was that she did not use the oven. Her husband, who is a

radiologist, gave it to her and she would not use it. He used it, but he did not have the cataracts.

I think we shall have to say that so far as the human being is concerned, we do not have sufficient knowledge.

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