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Prospects for treating AIDS infection with radio waves

Robert Gallagher and John Grauerholz, M.D. summarize a pioneering study recently presented to a conference of the Engineering in Medicine and Biology Society.

Last year Robert Gallagher, John Grauerholz, and Warren Hamerman of the EIR *Research division, submitted a paper, "On the Use of Electromagnetic Radiation to Prevent the Onset of Clinical Acquired Immune Deficiency Syndrome (AIDS) in Individuals Infected with Human Immunodeficiency Virus," for presentation at the Ninth Annual Conference of the Engineering in Medicine and Biology Society of the Institute of Electrical and Electronics Engineers. The paper was scheduled as the lead presentation in a conference session on "bioelectromagnetics," the study of the effects of electromagnetic radiation and fields on living organisms, and was also printed in the* Proceedings *of the conference.*

The authors decided that the most important task to accomplish at the conference was to educate scientists and engineers on the nature of AIDS and on the possibilities for investigating nonlinear effects of radiation on living organisms that may lead to discovering means to treat infection with the AIDS virus. Dr. Grauerholz presented the paper on Nov. 15, 1987 at the conference at the Boston Park Plaza Hotel. Afterwards, a Japanese physician commented that the paper was "the best discussion of AIDS" he had ever heard. The article below elaborates the conference presentation for a wider audience.

Experimental results reported by German and Russian scientists over the past 15 years indicate that low-intensity microwaves and other radio frequency radiation can selectively control the expression of the genetic material that regulates processes in the living cell. The effects depend on the frequency of the radiation applied.

These results are of particular importance because the development of the Acquired Immune Deficiency Syndrome (AIDS) following infection with the Human Immunodeficiency Virus (HIV), results from a problem in genetic expression within cells infected with the virus.

Research results indicate that with adequate funding, biophysicists may eventually be able to discover a combination of frequencies of radiation that can be used to treat the infection and postpone the onset of AIDS, or even "cure" the infected individual. By no means is this goal in sight. However, based on a review of existing results we can say that development of a treatment for AIDS infection is feasible. To make an analogy, we are now at a state of research similar to that which laser chemistry was in just after the laser was invented in 1960. Scientists knew laser chemistry was feasible, but exactly how to go about it was not yet known. However, research into the biological effects of radio waves is losing support. The budget for research in this area has declined 24% in real dollars since 1980 (see **Table 1**).

This article will review some important results on the selective nonlinear action of low-intensity microwaves on living organisms, potentially relevant to AIDS research. We first summarize some of the characteristics of the biggest public health threat to mankind today—the action of the HIV virus, and how it induces the human immune system to destroy itself.

How AIDS infection destroys the immune system

Acquired Immune Deficiency Syndrome is a disease process which unfolds in stages over time, and not simply an infection by an external agent that can easily be removed from the organism with the help of an antibiotic. Once infected with HIV, an individual is infected for life. HIV "hides out" in nerve cells and other organs in a latent form, even after the human physiology produces antibodies against the virus and virus proteins.

When HIV infects a cell, the genetic material of the virus is transcribed into a DNA "provirus" which is incorporated into the cell chromosomes in the nucleus, or persists in the nucleus outside the chromosomes in the form of "extrachromosomal DNA." The viral DNA may lie dormant across many cell divisions before the viral genetic sequence is "turned on," and the virus expresses itself, inducing the cell to produce virus and virus proteins, thereby turning the cell into a virus factory. What is in the nature of cellular reproduction that permits HIV-infected cells to express this deadly viral genetic material? How do healthy cells divide, as opposed to diseased cells? In either case, it is thought that electromagnetic radiation plays a critical role in cell division.

Each cell in the body is thought to contain the same total genetic sequence. In the cycle of cellular reproduction, in which one cell grows and divides into two daughter cells, the genetic material (DNA) of the parent cell is replicated to provide the genetic material for the daughter cells. It is thought that in this process of cellular reproduction, electromagnetic radiation, or "signals," within the cell, determine which genetic sequences are activated and which are not, in other words, how the cell differentiates. If an AIDS-infected cell can be sent the right "signal," perhaps expression of the AIDS proviral DNA can be prevented.

Research with millimeter waves indicate that it may be found that they could be used, to intervene directly to deactivate viral expression. Although millimeter waves don't penetrate deeply into living organisms, they could be transported to the sites of actual infection in the nervous system, or elsewhere in the whole organism, as a "chirp" on lower frequency waves (e.g., 200 MHz). In this way, they would be able to propagate through tissue that they usually would not be able to penetrate.

A form of treatment similar to renal dialysis may also provide some benefit, by passing the patient's blood outside the whole body environment to subject it to irradiation at specific frequencies and low enough powers so that the functioning of healthy cells in the blood is not impaired.

The research we summarize below, provides examples of how microwaves have been found to act "nonlinearly" to affect the expression of extrachromosomal or chromosomal DNA. First, we discuss some of the requirements that therapeutic techniques based on radio waves must meet.

Linear and nonlinear types of action

For radiation treatment to be effective therapy against viral infections, we must find frequencies of radiation that only affect the disease process, and do not disturb the healthy functioning of the physiology. The intensity of the radiation must be below levels at which it would begin to heat (and destroy) healthy living tissue; its action must be nonthermal. This requires that the action of the radiation upon the physiology be "nonlinear." That means it must be frequency-specific and independent of intensity.

Prior to some of the work that we will discuss below, it was almost universally believed in the West that nonlinear effects of radio frequency waves were not possible. Recently, the prestigious Max Planck Institute in the Federal Republic of Germany has declared after intensive study that nonlinear biological effects of radio frequency waves exist, and the phenomenon is gaining wider acceptance.

Effects of radio waves on genetic expression

Experimental results that show that externally applied microwaves can activate genetic sequences that are dormant in the healthy organism, were reported at the Scientific Session of the Division of General Physics and Astronomy of the U.S.S.R. Academy of Sciences in January 1973. A.Z. Smolyanskaya and R.L. Vilenskaya reported that irradiation of strains of human intestinal *E. coli* bacteria with specific wavelengths of microwaves, activated a portion of normally inactive extrachromosomal DNA that then induced the synthesis of a colicin, a protein that is poisonous to bacteria, within the cells. The *E. coli* died.

The colicins, also known as "bacteriocins," are a family of proteins, which kill bacteria by interfering with the energy systems of the cell, inactivating protein synthesis or degrading DNA and RNA function.

Smolyanskaya and Vilenskaya found that microwave-induced colicin synthesis, occurred at several wavelengths and only required a radiation intensity of 0.01 milliwatts per

TABLE 1

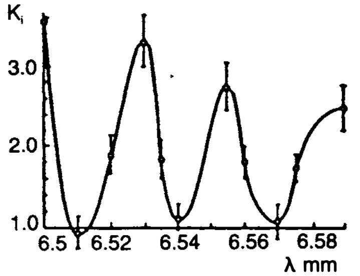
Funding for research in biological effects of radio waves ("bioelectromagnetics") has declined 24% since 1980

Fiscal year	Amount (thousands of 1980 dollars)
1980	$16,269
1981	$14,455
1982	$14,924
1983	$12,152
1984	$11,633
1985	$12,828
1986	$12,365

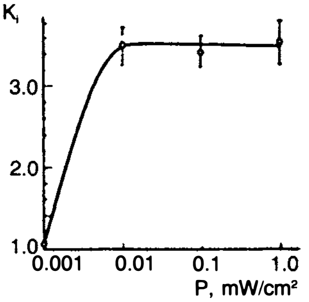
Source: Figures from *Bioelectromagnetics Society Newsletter*, May-June 1986, deflated with consumer price index.

FIGURE 1

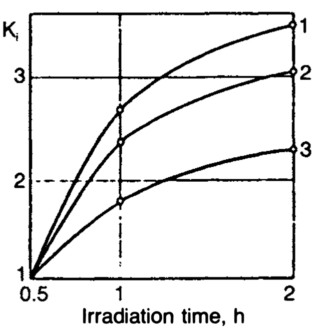
Specific frequencies of low-power microwaves induce bacteria to poison themselves



1a) *Russian scientists have reported that microwaves have induced expression of genetic material in bacteria that results in the synthesis of a poison, colicin, that killed the bacteria. The appearance of this effect, and its size, depended on the wavelength of the microwaves used. The figure shows the value of the coefficient of induction of colicin synthesis, K_i, as a function of wavelength.*



1b) *The effect on genetic expression occurred only after the power density at which the microwaves irradiated the bacteria had exceeded 0.01 milliwatts per centimeter squared of surface area. After the power density had exceeded this threshold, the effect did not change with further increases in power. Because the effect depends on frequency and not on power density, it is called "nonlinear."*



1c) *The time necessary to irradiate the bacteria to produce the effect also depended on the wavelength of the microwaves. The figure shows that the amount of colicin synthesized after 1 or 2 hours of irradiation varied by wavelength. Out of the three cases shown in the figure, microwaves 6.5 millimeters in length were most effective (curve 1), then waves 5.8 millimeters (curve 2), and then waves 7.1 millimeters (curve 3).*

Source: *Soviet Physics-Uspekhi*, Vol. 16, January-February 1974.

cm² with an irradiation time of one to two hours. Smolyanskaya and Vilenskaya wrote:

> Up to the present time, the ability of various agents (both physical and chemical) to induce the colicin synthesis which is lethal to the bacterial cell, has been linked basically to the ability of these agents to disintegrate DNA or block its synthesis. . . . From this point of view, millimeter-band radiation can be regarded as a fundamentally new agent that disturbs the functional regulatory mechanism of genetic elements in the cell, and extrachromosomic elements in particular, without causing direct damage to the DNA molecules.

Fig. 1a from their 1973 paper shows how colicin synthesis varied dramatically with the wavelength of the microwaves. The intensity of 0.01 milliwatts per cm² was a threshold for producing lethal colicin synthesis; below this intensity, the effect did not occur; above it, it did not grow in magnitude (see **Fig. 1b**). Thus the effect was nonthermal: It did not grow with intensity. The effect was nonlinear: It occurred only at specific frequencies and above a specific threshold of intensity. The magnitude of the rate of colicin synthesis varied with wavelength, not intensity (see **Fig. 1c**). Smolyanskaya and Vilenskaya wrote:

> That the effect does not depend on power is another weighty argument in favor of the nonthermal effects of millimeter waves, since all thermal effects depend primarily on flux intensity.

If microwaves can induce the expression of genetic material of *E. coli* bacteria, it is certainly conceivable that the appropriate frequency or mix of frequencies could *prevent expression* of the AIDS virus in cells infected with it.

Microwave effects on chromosomal DNA

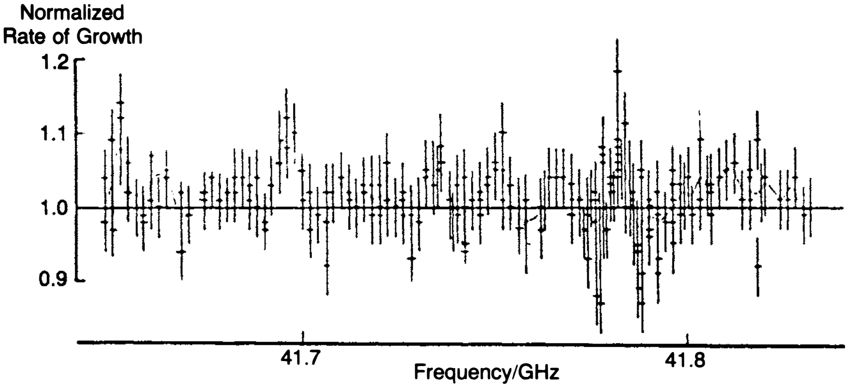
The experiments with *E. coli* show that microwaves can regulate the expression of DNA outside the chromosomes (extrachromosomal DNA). Can the function of chromosomal DNA also be affected by microwaves?

Experiments conducted in the Federal Republic of Germany by Werner Grundler of the Gesellschaft für Strahlen- und Umweltforschung and by Fritz Keilmann of the Max-Planck Institut für Festkörperforschung, have shown that specific frequencies of low-intensity microwaves can alter the rate of cell division in cell cultures of yeast. The rate of cell division and metabolism is regulated by chromosomal DNA, the genetic material in the chromosomes. Underlying a change in the rate of cell division or metabolism, must be a change in genetic expression of chromosomal DNA.

The results reported by Grundler and Keilmann were the result of a collaborative effort between three prestigious German research organizations—the Deutsche Forschungsgemeinschaft, the Gesellschaft für Strahlen- und Umweltforschung, and the Max-Planck Institut für

FIGURE 2

Microwaves can control growth rate of cell cultures



A West German research team has been able to vary the rate of yeast cell culture growth by varying the frequency of microwaves they use to irradiate the cells. The figure shows the response to the microwaves as a proportion of normal growth (1.0) over a spectrum of frequencies around 41.7 Gigahertz. Each point of the curve is an average of three experimental data points.

Source: *Physik in unserer Zeit,* 1985.

Festkörperforschung.

In *Physical Review Letters* in 1983, Grundler and Keilmann reported that the rate of cellular reproduction increased or decreased as much as 10% depending on the frequency of the microwaves used to irradiate the cell culture (see **Fig. 2**). In other words, cellular metabolism and reproduction "resonate" with specific wavelengths of microwaves. The effect was greatest at 41.78 billion hertz.

In an article in the German magazine, *Physik in unserer Zeit* (*Physics in Our Time*), Keilmann estimated that the radiation intensity required to produce this effect was only 0.1 milliwatts per cm^2, a level of intensity far below the level of 1-10 milliwatts per cm^2 traditionally expected in the West to be required to produce any significant effect at all. The probability that the spectrum of frequency-specific responses shown in Fig. 2, was the result of mere chance was calculated to be less than 0.0002.

These early experiments confirmed work on yeast reported by N.D. Devyatkov at the 1973 Session of the the U.S.S.R. Academy of Sciences and thus gave credence within the West to other Russian work presented at that conference, such as the results with *E. coli* described above.

In more recent experiments, Grundler and Keilmann have attempted to isolate just where in the cell cycle the microwaves act. The latest results provide further evidence that microwaves act on cellular genetic material. They investigated the effects of low-intensity microwaves on individual yeast cells over several cell divisions that produce a "microcolony" of four to eight cells. The results will appear in *Biological Coherence and Response to External Stimuli,* edited by H. Frölich, which is scheduled for publication over the next year by Springer-Verlag publishing house, Berlin. *EIR* obtained a pre-publication copy of the report in which the authors are Grundler, Keilmann, Udo Jentzsch, and Vera Putterlik.

Effects on specific phases of cellular reproduction

The yeast cells used in these experiments were "synchronized" with respect to the phase of cellular reproduction that they were in. Each cell had been stored at 4° centigrade in a stationary state in the "G1" or first growth phase of the cell reproduction cycle, the phase in which the cell grows in size prior to synthesizing the genetic material (DNA) required for the daughter cells in the "S" or "synthesis" phase of the cycle. The experimentalists then followed the course of cellular division in response to continuous microwave exposure over at least two full generations (see **Fig. 3**).

The purpose of these experiments was to investigate whether the response was related in any way to a specific phase of the cell cycle, or was expressed only after a specific number of cell divisions following the onset of irradiation. Did the effect occur during all cell divisions of a parent into two daughter cells, or only after a "threshold" number of generations?

In the experiments, Grundler and Keilmann examined the variation in cellular reproduction in response to microwaves over the frequency spectrum from 41,760 to 41,800 megahertz, where the strongest effects had been found earlier. They found that almost the entire effect of the microwaves in increasing (or decreasing) the rate of cell division, occurred after the first generation. After at least two cells were present—forming a "micro-colony," then effects of the microwaves appeared in the rate of reproduction of these daughter cells in the second cell division (known as the "F2" division of a cell-line). The effect on the first cell division was very small (see **Fig. 4**).

The new Grundler-Keilmann results are consistent with the "F2 hypothesis" circulating within the biophysics community. That hypothesis holds that the effects of radio frequency electromagnetic radiation are expressed in the second cell division, after the radiation intervenes in the normal synthesis of DNA in the S-phase of the first cell division. Grundler and Keilmann conservatively state that the microwaves in their experiments are affecting metabolic processes, and pass over the fact that changes in metabolism are probably due to changes in the genetic regulation of metabolism. How is it possible for microwaves to interfere with the synthesis of DNA in the S-phase? We will propose an answer to this question below.

Do microwaves affect higher organisms nonlinearly?

Successful demonstrations that resonant microwave effects upon expression of cellular genetic material exist within laboratory cell cultures of yeast and *E. coli* bacteria, is encouraging for the prospects of the therapeutic application of radio waves to the sort of disorders in genetic expression found in AIDS, but other important criteria must be met.

1) Have any nonlinear effects of radio waves on biological processes been found in irradiation of more highly organized mammalian cells?

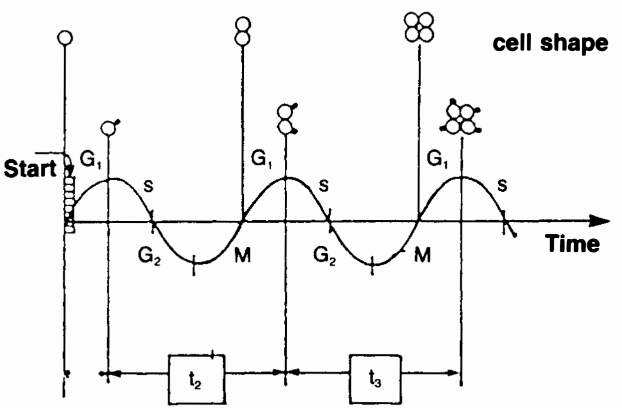
2) Do the effects persist *in vivo,* that is, when the intact whole organism is exposed to low-intensity radio waves?

These are important questions for the development of any low-intensity radio-therapy. Higher organisms are more resistant to intrusion from the external environment. If low-intensity radio frequency electromagnetic radiation does not affect their cellular processes resonantly, prospects for therapeutic treatment become dim. However, if the effect were resonant, this would confirm that the mechanism of action of microwaves upon the intracellular environment is coherent with fundamental electromagnetic interactions critical to cellular reproduction; if this radiation were not consistent with the intracellular environment, it would quite probably be screened out.

L.A. Sevastyanova and R.L. Vilenskaya reported in 1973 on experiments that demonstrate that resonant microwave effects occur in mammals *in vivo,* such as in the bone marrow of living mice. *In vivo* exposure of mouse bone marrow to

FIGURE 3

Experimental plan for investigating rate of cell division

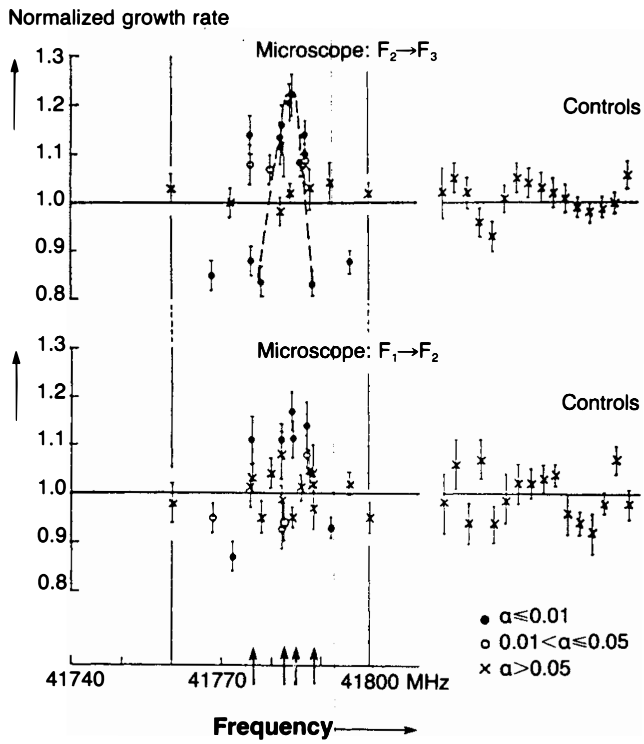


The German research team studied the effect of microwaves on the speed of cell division from single yeast cells. They studied the formation of a microcolony of four cells from one over two cycles of cell division, using the appearance of the "bud" in the first growth phase of cellular reproduction (the G_1 phase) as an event to mark the time (t) from division to division.

Source: W. Grundler et al., "Resonant Cellular Effects of Low Intensity Microwaves," Fig. 9, preprint of paper to appear in *Biological Coherence and Response to External Stimuli,* ed. by H. Fröhlich, Springer-Verlag, Berlin, 1987/88.

FIGURE 4

Effects of microwaves only appear after the first cell division



The German research team discovered that the effect of microwaves in increasing the rate of yeast cell division, shows up primarily in the second full cycle of cell division after the cells are exposed to the radiation. The figure shows the growth rate relative to the average growth rate of cells not radiated (1.0, the "controls" at left). The bottom figure shows how the frequency of microwaves influences the relative speed of the first full cell division; the top figure shows how the frequency of microwaves influences the relative speed of the second full cell division.

Source: W. Grundler et al., "Resonant Cellular Effects of Low Intensity Microwaves," Fig. 10.

microwaves by irradiation through the skin prior to exposure to x-rays had a therapeutic effect, and this effect was resonant with specific frequencies of microwaves. They found that microwave irradiation of the intact left pelvis at specific frequencies, decreased the amount of damage to the marrow induced by the subsequent x-ray irradiation. The authors wrote: "The dependence of the effects of exposure on frequency is of an acutely resonant nature." This result is particularly interesting since immune system cells arise from bone marrow. The ability to selectively act on bone marrow, is encouraging for the prospects of acting selectively on a diseased immune system.

In addition to finding a resonant effect in the cellular processes of a live mammalian organism, Sevastyanova and Vilenskaya discovered that above a threshold of 10 milliwatts per cm², the effect was independent of intensity. Below a power density of 10 milliwatts per cm², the protective effect induced by microwaves did not occur; at that intensity and above it, the effect was always the same: Once the threshold of 10 milliwatts per cm² was exceeded, the effect was independent of intensity. After 60 minutes of pre-treatment with microwaves, x-ray irradiation decreased the number of bone marrow cells by only about 20% (see **Fig. 5a**), versus the 50% decrease measured in the absence of therapeutic pre-treatment with microwaves.

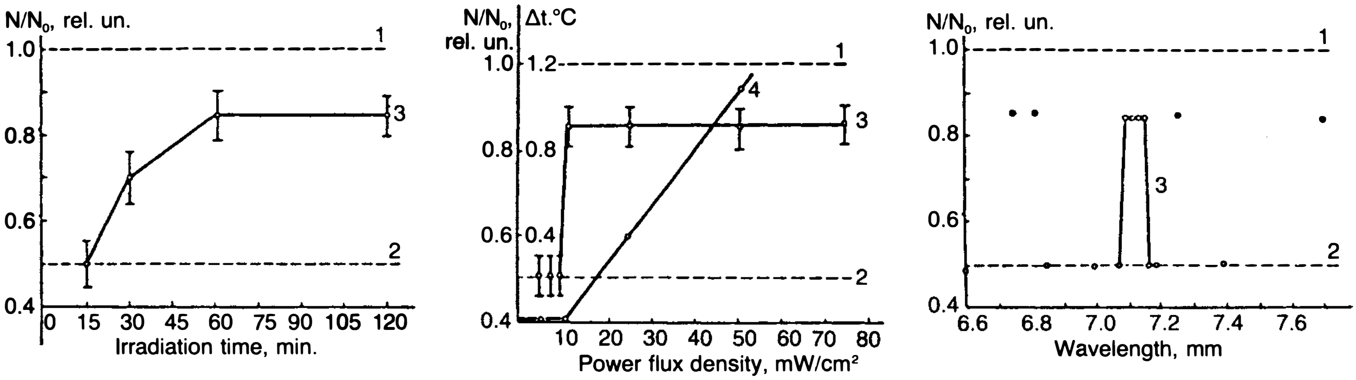
In the experiment, the microwaves were applied to the intact organism; bone marrow was not irradiated directly. Indeed, millimeter waves barely penetrate the skin of the organism. In a discussion of these experiments, Grundler estimated that 70% of the power applied to the organism was absorbed by the skin. Only a small fraction of the power, less than 3 milliwatts per cm², penetrates into the underlying tissue, and even less into bone itself. Thus although the applied power density (10 mW/cm²) is at the level of microwave thermal effects, the effective power density was much lower; the effect on the bone marrow itself was nonthermal, resonant, and nonlinear. The fact that the effect remained the same for intensities from 10 to 80 milliwatts per cm² (see **Fig. 5b**), and occurred only at specific wavelengths of microwaves (see **Fig. 5c**), demonstrates this.

Effects on viruses in cell cultures

Other work presented at the 1973 Lebedev conference, discussed the use of millimeter waves to decrease the infec-

FIGURE 5

Microwaves protect bone marrow from effects of x-rays



5a) *Russian scientists have reported that irradiation of live mice with microwaves, protects their bone marrow cells from the damaging effects of x-ray radiation. After 60 minutes of pretreatment with microwaves, x-ray radiation reduced the number of bone marrow cells by only 18% (curve 3) from normal (curve 1). Without pretreatment with microwaves, the x-ray dosage used reduced the number of cells by 50% (curve 2). The data is shown in units relative to the normal number of cells.*

5b) *This therapeutic effect of microwaves appeared only after the power of the microwaves applied exceeded a threshold radiation intensity of 10 milliwatts per centimeter squared of surface area. If the power density was increased above this level, the protective effect still existed, but it did not change in magnitude. The number of cells protected did not increase (curve 3). The only effect of higher power densities was to increase the skin temperature of the mice (curve 4). Curve 1 shows the number of bone marrow cells without any radiation; curve 2 shows the number of bone marrow cells after x-ray dosage only.*

5c) *The appearance of the protective effect depended dramatically on the wavelength of microwaves used in the experiments. The small circles in the figure mark the wavelengths used in the experiments. Only specific wavelengths produced the protective effect (curve 3). Others produced no effect (curve 2).*

Source: *Soviet Physics-Uspekhi*, Vol. 16, January-February 1974, p. 140, Figs. 1, 2, and 3.

tiousness of viruses in cell cultures. R.I. Kiselev and N.P. Zalyubovskaya reported that:

> Millimeter-wave irradiation of various viruses (adenoviruses, measles virus, vesicular stomatitis virus, and others) resulted in a quantitative reduction of the virus particles (on radiation of the whole virus) by a factor of 2-3. Lowered infectious activity of irradiated adenoviruses and measles virus was manifested in a delay of the cytopathogenic effect on a tissue culture.
>
> A decrease in infectious activity was observed after irradiation of virus DNA preparations (isolated from adenoviruses) as compared to unirradiated specimens. . . .
>
> The data obtained may serve as a basis for the use of millimeter-band electromagnetic waves in experiments toward controlled modification of viruses and other microbes.

How do radio waves act on living organisms?

We have reviewed experimental results that show that low-intensity radio waves can affect genetic expression and other processes in living organisms in a manner that is specific to the frequency of the radiation applied. All in all, they demonstrate that the feasibility of a research program to develop means of using radio frequency electromagnetic radiation to treat AIDS infection is well established. Much research remains to be done. We require a "Biological Strategic Defense Initiative" in biophysical research to blaze the path toward a viable form of treatment of infection with the deadly AIDS virus. Research on nonlinear radio frequency bio-effects must proceed along a broad front, while more specialized research programs with the AIDS virus and AIDS-infected cell cultures are conducted in high-security laboratories.

In order to guide research in the area of nonlinear effects of radio waves so that future research will result in the fastest progress toward mastering these phenomena for medical applications, it is important to formulate hypotheses about what biophysical characteristics might be making the nonlinear effects of radio waves possible. The following questions must be addressed.

1) How can microwaves affect the processes of cells whose dimensions are thousands of times smaller than their wavelength? In the yeast experiments of Grundler and Keilmann, the cells used were about 30 cubic micrometers, roughly a few micrometers across. The wavelength of the microwaves used was about 7,180 micrometers (7.18 millimeters), roughly 2,400 times the width of the yeast cells. Obviously there is more to radio frequency wave effects than the mere spatial interaction of the radiation with cellular material.

2) How can radiation with an energy that is tremendously lower than that required to break chemical bonds, and even lower than the thermal energy attributed to molecules in living organisms, affect cellular processes? The elementary unit of electromagnetic radiation is the "photon"—a unit of an electromagnetic radiation equal to one full rotation of an electromagnetic wave. High-energy ultraviolet photons are required to break chemical bonds. They have an energy of several "electron volts." By comparison, microwaves have an energy less than 0.001 electron volts, yet they are capable of inducing frequency resonant changes in cell function.

3) The intensity of "random" thermally induced collisions assumed to occur inside a living cell at 27° centigrade, is 25 times greater than the energy of the most energetic microwaves. Statistical thermodynamics holds that this thermal excitation is 0.025 electron volts in energy, and that it would smear out of existence any effects of lower energy forms of action; the experiments discussed here show that this concept doesn't hold for living systems.

4) The spectra of frequencies that dead biological material absorbs do not show the sharp "resonance lines" observed in the experiments with living cells or whole organisms. In the yeast experiments, if the frequency of the microwaves used was changed only a few megahertz from 41,780 MHz, where the growth effect was maximal, the effect completely disappeared. The width of the frequency band over which the effect occurred was 8 MHz. Resonances in dead tissue are tremendously broader—making selective action by microwaves practically impossible. What produces this qualitative difference in the frequency spectra between living things and dead tissue?

In developing hypotheses to explain radio wave effects, we will find the results of work in nonlinear laser chemistry very useful. In laser chemistry and chemical physics, coherent radiation of wavelengths resonant with the "quantum transitions" of molecules we seek to act upon, is used to excite the molecules into different "energy states" where they will react chemically with other molecules in a different way than they would otherwise. The molecule is said to absorb a photon of the electromagnetic radiation, to be "excited" into a different energy or quantum state in which it becomes capable of participating in reactions it otherwise could not.

Quantum states of molecules are distinguished by the arrangement and behavior of their electrons or atoms. A transition, from one quantum state to another, is said to be an *electronic* transition, when it involves some rearrangement or loss of the molecule's electrons. Most electronic transitions in molecules or atoms are high-energy transitions, requiring absorption of photons of light in the ultraviolet portions of the electromagnetic spectrum. Since the energy of a photon decreases with the frequency of radiation, radio frequency electromagnetic radiation is not ordinarily expected to produce electronic transitions in molecules. There are, however, low-frequency electronic transitions of molecules among what are called their "multiplet" states—conditions of molecules that differ by the orbital motion of their electrons. These are produced by an effect of the magnetic field generated by the molecule itself. Because it is a magnetic effect, it is effective at even low intensities. Keilmann has put forward a hypothesis to explain the sharp resonant action of microwaves that his lab discovered in yeast, based on transitions among multiplet states.

Multiplet states are quantized, that is, there is always an integral number of possible states of the electrons' orbital motion; technically speaking, this means there is always an integral number of possible values to their total orbital angular momentum. If there are three possible values of the electrons' total orbital angular momentum, the molecule is said to be a "triplet" molecule. Quantum transitions among triplet states in many organic molecules are produced by frequencies of electromagnetic radiation as low as 3 gigahertz in the microwave portion of the radio frequency spectrum.

Transitions among triplet states are known to play a role in photochemistry and laser physics. V.S. Letokhov of the Institute of Spectroscopy of the U.S.S.R. Academy of Sciences wrote in *Nonlinear Laser Chemistry* that: "The excitation to a singlet state and the subsequent transition to a longer-lived triplet state forms the basis of most photochemical reactions in solution." Depending on various factors, subsequent excitation to another triplet state can occur. "Such singlet-singlet and triplet-triplet transitions are well known in quantum electronics," Letokhov adds, "for example, in the solutions of dyes used in some [dye] lasers."

For transitions involving triplet states, many organic dye compounds, such as those used in dye lasers, have a high quantum yield, that is, the proportion of light they radiate to the light they absorb is high. For acridine orange, the triplet yield is as high as 10%. Acridine orange is one of the organic dyes that has been found to induce the coiled DNA helix to unwind and rewind itself. Perhaps this action is related to the dye's electromagnetic characteritics as a triplet molecule. This would certainly be consistent with the "F2 hypothesis," that microwaves effect cellular processes by intervening in DNA synthesis in the S-phase of cellular reproduction.

In a paper published in 1986 in *Zeitschrift für Naturforschung*, Keilmann concluded:

> Nonthermal populations quite generally appear when triplet molecules are formed. . . . Since the overall chemical reactivity of a molecule depends on its [multiplet] substate, the result [of changing it] is an overall change of the molecule's reaction rate which may cause further changes in the biochemical pathway . . . the experimental resonance frequency should be apt to serve as a fingerprint to identify the target molecule . . . it might turn out that resonant microwaves provide the selectivity necessary to pinpoint specific target molecules or sites in complex *in vivo* systems.

We have said little so far about the resonant, nonlinear action upon cellular processes of radio waves with frequencies lower than microwaves. For the moment, we note that hypotheses regarding triplet states may be of some value here as well. The frequency of action of radiation required to excite a molecule from one multiplet state to another, varies with the magnitude of externally applied magnetic or electric fields. Slowly varying extremely low frequency (ELF) radio waves, produce transient electromagnetic fields that would effect the "size" of a triplet-triplet quantum transition so that effects achieved with millimeter waves, could be accomplished with ELF waves modulated in the long microwave or megahertz portions of the radio frequency spectrum.

The questions we have discussed here are at the frontiers of research in optical biophysics, the investigation of the electromagnetic properties of life. The wonderful thing about this subject is that there are many more questions than there are answers. Posing the right questions is the first step in fundamental research. For example, what electromagnetically, distinguishes the nature of healthy biological processes from diseased ones? In answering this, we will go a long way toward finding a treatment or cure for AIDS infection.