

Microwaving Our Planet:
The Environmental Impact of the Wireless Revolution
ARTHUR FIRSTENBERG 1997
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Mindfully.org note:

Be sure to read Arthur's latest article, which appears in The Ecologist (June 2004).

"Killing fields - As the world turns digital and remote, an invisible cloud of electrosmog is putting the health of millions at risk."

Contact him at: PO Box 1337, Mendocino CA 95460, telephone: 707-937-3990 (voicemail)

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This is an urgent plea to environmentalists and to those within the telecommunications industry, to doctors and businesspeople and government officials, that microwave radiation is an imminent danger to all of us more or less equally, and that for our common survival we must immediately halt the expansion of wireless communications upon this earth. There is no greater threat to our common future.

Arthur Firstenberg
June 22, 1997
Norwich, NY

INTRODUCTION

From Bill Gates' planned fleet of 300 satellites to the millions of ground based antennas being constructed through-out the world, our privacy is being invaded, our health undermined, our water polluted, endangered species threatened, the ozone layer destroyed, and our climate altered. The assault has already begun.

The purpose of this report is to give a general overview of the environmental threats associated with the wireless revolution, and an in-depth review of 70 years of research into the health hazards of microwaves.

The lack of an adequate review of the literature until now has led to the incorrect perception that the scientific evidence is contradictory and inconclusive. In fact the scientific evidence is consistent and overwhelming.

Satellite systems

In 1957 there were no artificial satellites in the sky above us. Today there are thousands. The list of countries that have launched satellites to date is huge: the United States, Canada, Mexico, Brazil, Argentina, France, Germany, Norway, Sweden, Spain, England, Russia, Turkey, China, Japan, Indonesia, India, Thailand, Korea, Malaysia, Australia, New Zealand, Tonga, the European Community, Eastern Europe, the Arab League, Pan-Asia, and Intelsat (125 nations). Multinational corporations are sending up

fleets. Even small private entrepreneurs are filling up the heavens with smaller, cheaper hardware. Whether a cellular phone company wants to provide global service, or a rancher in Australia wants to know the whereabouts of his cows, satellite technology will do the trick.

Ground based towers

The existing network of ground based antenna systems is not good enough. The telecommunications industry says it will need 270,000 more facilities immediately just in the United States (Microwave News, May /June 1996, p. 10), and comparable numbers elsewhere in the world. These are going up on lampposts and apartment buildings in cities, and on fresh eyesores throughout the suburbs, countryside and wilderness.

In addition, satellite systems, which shine very weakly on us, need to communicate with their own network of powerful earth stations. These stations will proliferate along with the satellites.

Pandora's box

Until recently almost all radio transmitters have been fixed and their range limited. The addition of more broadcast channels and new types of communication devices did not change that. But with the advent of cellular technology, all limits have been lifted. Telephones are no longer just communicators but also transmitters, and they are mobile. Suddenly every human being is a potential source of radiation. Suddenly electronic communication is a human right. Suddenly fixed transmitters and satellites are being built to accommodate mobile human beings, rather than the other way around.

Electromagnetic pollution will no longer remain concentrated in population centers, nor will radio transmitters be confined any longer to non-residential zones. In the space of a year or two, unless the people put a stop to it, this form of pollution will be spread more or less evenly over every square inch of the world.

The power is small, but the reach is unlimited.

There are among us today television towers that broadcast with a radiated power of 5 million watts. How much damage could the radiation from cellular equipment do by comparison? one might ask. Each antenna on a rooftop or tower generally emits less than 1000 watts, with 10-150 watts being the norm for lampposts and the sides of buildings.

The answer is surprising. If you live 10 miles from a 5 million watt television station, you will receive more radiation from a cellular antenna that is on a lamppost on your block than you will from that TV station. And by U.S. law, a 5 million watt TV station must be separated from other stations of similar frequency by a distance of at least 175 miles. Cellular transmitters are far less restricted: they can and will proliferate without limit. And they can and will increase their broadcast power if it is profitable to do so. The new legal limit is 3500 watts per channel per transmitting station, with no limit at all on the number of channels or the number of towers or the number of companies broadcasting in the same area.

Television signals also do not reach beyond line-of-sight from the tower, and are blocked by hills and buildings. The cellular transmitter is going to be right there where you are, anywhere on earth. You are no longer going to have the option of limiting your radiation exposure by living distant from antennas.

Health hazards

Microwave radiation is dangerous. As everyone knows, high levels will cook you. Low levels will also harm you in other ways.

Another type of radiation that coming from electric power lines has been much more in the news in previous years. There is now a growing scientific consensus that the 60-cycle radiation from power lines is dangerous and can cause cancer, leukemia and other diseases. Fortunately the distribution of electricity is not yet wireless, and most of the earth's surface is still remote from high-tension wires.

Power line radiation (50 or 60 cycles per second, or hertz) is especially harmful because it is close to the frequency of brain waves. Microwave radiation is especially harmful because the wavelengths are smaller than our bodies. This radiation is therefore selectively absorbed by our bodies.

Table 1

	maximum frequency(Hz)	wavelength
power lines	60	3000 mi.
AM radio	1,600	600 ft.
short wave radio	30,000,000	30 ft.
FM radio	108,000,000	10 ft.
TV channels 2-13	216,000,000	5 ft.
TV channels 14-69	806,000,000	1 ft.
cellular phones	947,000,000	1 ft.
PCS	2,400,000,000	6 in.
satellites	50,000,000,000	1/4 in.

Smaller waves are better absorbed by smaller body parts and smaller people (children).

Cellular transmitters are not only going to be more common than any transmitters have ever been before, they are also broadcasting at the most dangerous frequencies.

And this radiation will be doubly dangerous because all the new technology is going to be digital. Digital signals come in pulses, rather than continuously as is now the case, and pulsed radiation has been found by most investigators to be more injurious to living things at lower average levels of power than continuous radiation.

Government safety standards

In the United States the Federal Communications Commission has set standards of permissible irradiation of the general public. These standards are based on thermal hazards only, the assumption being that if microwaves aren't strong enough to cook you, they will do you no harm. For cellular telephone systems, exposure is permitted to power densities of 533 to 1000 $\mu\text{W} / \text{cm}^2$ (microwatts per square centimeter), depending on the frequency. These standards are at least ten million times the level which probably still exists over most of the surface of the earth, and at least ten billion times the level of microwaves we receive naturally from the sun and stars. They are also at least two hundred thousand times greater than what even most city residents have been exposed to until very recently (Tell and Mantiply 1980, Solon 1979, Zaret 1974, Szmigielski and Gil 1989).

Table 2 - Exposure levels ($\mu\text{W}/\text{cm}^2$)

average stellar signal	.000000000000000000000001
cosmic radiation, 10 MHz	.0000000000000000008
from a quiet sun, all freq.	.0000000001
from one cellular satellite	.0000001
in Tottenville, N.Y.C. 1978	.000068
average New York City 1979	.002
300 ft. from a cellular tower	5.0

in Empire State Building 1978	32.5
in Sears Tower 1978	65.7
F.C.C. Safety Standard 1996	1000.0

We can reasonably expect the radiation levels over most of the habitable parts of the earth to increase 1000-fold just as a beginning result of the current cellular expansion. How high those levels eventually will go is anybody's guess.

The danger, even if we didn't have epidemiological studies, is evident. We cannot expect to increase the irradiation of the entire earth 1000-fold or more virtually overnight without health effects and without massive biological consequences. Indeed this technology is more invasive than virtually any other and has the potential of causing worldwide catastrophe.

REVIEW OF THE LITERATURE

The scientific literature is full of thousands of studies of the health effects of microwaves at power levels of 1-10 mW / cm². I will not review those here. Supposedly those levels of exposure are not enough to cause heating of the body, yet the defenders of the 1 mW / cm² (1000 μW / cm²) safety standard dismiss any effects shown at those levels as heating effects. The absurdity of their position seems to escape them. But I will bypass their entire argument by only reviewing studies that show health effects at exposure levels of 500 μW / cm² or less all the way down to .000000026 μW / cm².

Contrary to general belief, this body of literature is consistent and not contradictory. Microwaves impact most obviously the nervous system and the heart. There is generally not a linear dose-response effect, and there is not a threshold below which there is no effect. An effect seen at low intensity will not necessarily be seen at high intensity, nor vice versa. Because the impact is cumulative, short-term experiments will not give the same results as long-term experiments. Often more than one type of effect will be seen in the same group of experimental subjects; therefore averaging the results may lose information. In light of all this, the kinds of studies that are doomed to obtain negative findings are those done at high intensities, short term, looking for thresholds and linear dose-responses, and averaging all their data. In this is consistency also.

Some of the early animal experiments have been criticized because metal objects near the animals may have distorted the field and increased their radiation dose beyond what was reported. However, the more recent work (since the mid 1970s) has all been done in carefully shielded enclosures with no metal wires or objects, and has produced the same results. In any case, what we are trying to gauge here is the effect on human health, and none of us live in shielded houses devoid of wires or metal objects. The earliest research is therefore just as relevant to the human situation as the most recent, if not more so.

1. The nervous system

Radiation sickness.

Symptoms that may occur include headache, fatigue, weakness, sleep disturbances, irritability, dizziness, memory difficulty, emotional instability, depression, anxiety, sexual disorders, skin markings, rash, burning sensation in the face, acrocyanosis (blue fingers and toes), sweating, tremors, accentuated tendon reflexes, decreased abdominal reflexes, unequal pupil size, and unstable pulse and blood pressure. These symptoms were consistently found in controlled studies of workers exposed to various frequencies of microwaves on the job, by:

Sadchikova (1960) in a clinical study of 525 workers exposed to microwave generating equipment. Those exposed to hundreds of microwatts per square centimeter or less had symptoms more often than those exposed to higher intensities.

Sadchikova (1974) in a clinical study of 1180 workers. Here too those exposed to lower intensities had more frequent symptoms than those exposed to higher intensities. Certain types of changes, for example hypotension and bradycardia, were more frequent at high intensities.

Klimkova-Deutschova (1974) in a clinical study of 530 workers from 29 places of employment.

Baranski and Edelwejn (1975) in a study of workers in the Military Institute of Aviation Medicine, Warsaw.

Zalyubovskaya and Kiselev (1978) in a clinical study of 72 engineers and technicians.

Bachurin (1979) in a clinical study of 100 television, radio, and other workers exposed to 20-60 $\mu\text{W} / \text{cm}^2$ and up to 100 $\mu\text{W} / \text{cm}^2$ on occasion. Photophobia was also noted in an occasional worker.

Sadchikova et al. (1980) in a clinical study of 50 industrial workers exposed to several hundred $\mu\text{W} / \text{cm}^2$.

Huai (1981) in a clinical study of 841 workers in 11 factories and institutes, including 238 people exposed to less than 50 $\mu\text{W} / \text{cm}^2$.

Gorbach (1982) in a clinical study of 142 workers exposed to microwave equipment.

Trinos (1982) in a clinical study of 2247 workers at 2 industrial plants.

Markarov et al. (1995), in a clinical study of 53 workers exposed to regular low-dose radiation.

Several cases of psychosis have been described in workers with objective signs of radiation sickness. These patients developed symptoms of mania and paranoia that did not fit the pattern for schizophrenia and were treatable only by removal from exposure to radio waves (Chudnovskiy et al. 1979).

Baranski and Czernski (1976) wrote, "The pathogenesis of these syndromes may be controversial but their existence can-not be denied. Similar observations were made by Miro in France, and in the United Kingdom and the United States, according to a personal communication made by Mumford to Seth and Michaelson" (p. 168).

Sensory thresholds.

Bourgeois (1967), in an experiment with 36 young men 18-25 years of age, found that a two-minute exposure to 500 $\mu\text{W} / \text{cm}^2$ of 1000 MHz radiation significantly lowered their auditory threshold, i.e. made them more sensitive to sound. Both continuous and amplitude modulated waves had this effect.

Lobanova and Gordon (1960), in a clinical study of 358 workers 20-35 years of age occupationally exposed to low-level

microwaves, found that a majority had either abnormally high or, more often, abnormally low sensitivity to odors. A change in olfactory sensitivity was found to be one of the earliest signs of microwave influence.

Baranski and Czernski (1976) review several studies which show that chronic microwave exposure also decreases auditory, visual, and skin sensitivity, both clinically and in EEG studies.

EEG.

Changes in the electroencephalogram show a generalized inhibition of the central nervous system as well as certain specific pathological patterns.

In addition to general inhibition, Klimkova-Deutschova (1974) found small but specific changes in the EEG of many workers exposed to microwaves in the 3-13 centimeter band. This included synchronized slow waves of high amplitude, similar to those seen in epileptic seizures. The EEG was said to be an

important diagnostic tool that objectively shows micro-wave effects even when clinical signs are only slight.

Baranski and Edelwejn (1975) reported that workers with the longest occupational exposure to microwaves generally exhibit flat EEG recordings.

Huai (1981), in an examination of 106 microwave-exposed workers, found an increase in slow (theta and delta) waves on their EEG.

Mann and Roschke (1996) exposed 14 healthy male volunteers 21-34 years of age to a digital cellular phone during the night at a distance of 40 cm., so that the power density reaching their head was $50 \mu\text{W} / \text{cm}^2$. Specific alterations in their EEG were noted. The radiation also caused a significant decrease in the amount of REM sleep.

Sikorski and Bielski (1996) found abnormal glucose tolerance tests in 31 of 50 workers exposed to radio waves. Of these, 10 also had abnormal EEGs.

Experiments on animals.

Acute low-level exposure to microwaves stimulates the nervous system, while chronic exposure suppresses it. This has been confirmed in animals by behavioral changes, EEG changes, lowered levels of neurotransmitters, lowered levels of the respiratory enzyme cytochrome oxidase, and cell damage as seen in the electron microscope.

Gvozdikova et al. (1964) exposed groups of chinchilla rabbits to 12.5 cm., 52 cm., and 1 m. radiation for 5 minutes. 81% showed changes in the EEG when exposed to $20 \mu\text{W} / \text{cm}^2$.

Frey (1967) induced evoked potentials in the brain stem of cats with pulsed 1200-1525 MHz waves at an average power density of $30 \mu\text{W} / \text{cm}^2$.

Giarola et al. (1971) observed a tranquilizing effect on chickens and rats at $24 \mu\text{W} / \text{cm}^2$ using 880 MHz waves.

Dumanskij and Shandala (1974) irradiated 228 white rats and 60 rabbits, 8-12 hours a day for 120 days. Inhibition of conditioned reflexes was produced by 6 meter waves at $1.9 \mu\text{W} / \text{cm}^2$, and by 3 centimeter waves at $5 \mu\text{W} / \text{cm}^2$. Definite EEG changes were noted even at $0.06 \mu\text{W} / \text{cm}^2$ for the 6 meter waves: an initial excitation of the nervous system gave way to synchronized rhythms and then to general inhibition during the course of the experiment. "Electromagnetic energy in the UHF range and $0.06-10 \mu\text{W} / \text{cm}^2$ intensity was indeed active biologically according to the results of statistical analysis" (p. 291). Other indicators of nervous system activity cholinesterase and sulfhydryl groups in the blood were also significantly lowered at $1.9 \mu\text{W} / \text{cm}^2$.

Gabovich et al. (1979) found that $100 \mu\text{W} / \text{cm}^2$ for 2 hours a day first increased the work capacity of rats and later decreased it. It also affected the latent period of unconditioned reflexes, altered sleep, and lowered cholinesterase activity in the blood and the brain. The frequency was 2375 MHz, continuous mode.

Grin' (1978) found that $50 \mu\text{W} / \text{cm}^2$ increased epinephrine, norepinephrine, and dopamine in the brain of rats after 7 hours a day exposure for a month. The wavelength was 12.6 an. $500 \mu\text{W} / \text{cm}^2$ decreased the levels, and exhausted the adreno-sympathetic system.

Dumanskiy and Tomashevskaya (1978) found a 20-26% decrease in cytochrome oxidase, a respiratory enzyme, in brain mitochondria, after 4 months exposure of rats. The frequency was 2375 MHz, continuous wave, and the power was $100 \mu\text{W} / \text{cm}^2$. Another enzyme, glucose-6-phosphate dehydrogenase (G-6-PDH), rose 20-28% in compensation.

In a 4-month experiment with 1200 albino rats, Dumanskiy et al. (1982) found an increased skin sensitivity to electrical stimulation, decreased work capacity and altered conditioned reflexes at $25-60 \mu\text{W} / \text{cm}^2$. $40 \mu\text{W} / \text{cm}^2$ activated blood cholinesterase, while $115 \mu\text{W} / \text{cm}^2$ inhibited the enzyme. The wavelength was 3 cm.

Shandala et al. (1979) exposed rabbits to 2375 MHz waves for 7 hours a day for 3 months. $10 \mu\text{W} / \text{cm}^2$ stimulated the electrical activity of the brain. $50 \mu\text{W} / \text{cm}^2$ stimulated brain activity for 30 days, then gradually inhibited it. At $500 \mu\text{W} / \text{cm}^2$ inhibition began within 2 weeks. In rats, $500 \mu\text{W} / \text{cm}^2$ decreased behavioral search activity, suppressed the food response, and decreased work capacity. $10 \mu\text{W} / \text{cm}^2$ and $50 \mu\text{W} / \text{cm}^2$ had the same suppressive effect on the nervous system after 30 days, and increased the sensitivity of the skin to electrical irritation.

Shutenko et al. (1981) exposed rats to 2375 MHz waves for 2 hours a day for 10 weeks. $10 \mu\text{W} / \text{cm}^2$ inhibited unconditioned reflexes, and lowered cholinesterase in blood and brain tissue.

Belokrinitskiy (1982a) found an increase in the activity of the enzymes succinate dehydrogenase (SDH), malate dehydrogenase (MDH), lactate dehydrogenase (LDH), and G-6-PDH, and a decrease in levels of glycogen and RNA in the cells of the brain and other organs of rats after chronic exposure to $5 \mu\text{W} / \text{cm}^2$, and after a single 3-hour exposure to $50 \mu\text{W} / \text{cm}^2$. Two months of exposure to $10 \mu\text{W} / \text{cm}^2$ damaged the mitochondria, the endoplasmic reticulum, and the nucleus of cells. These changes did not revert to normal within one month. $1000 \mu\text{W} / \text{cm}^2$ produced much more drastic cell changes. $10 \text{mW} / \text{cm}^2$ (supposedly "non-thermal" and safe!) swelled cells, altered their shape, damaged blood vessels, demyelinated nerve fibers, etc., after just one hour exposure of cats. The wavelength was 12.6 cm.

In another experiment, Belokrinitskiy (1982b) found damaged neurofibrils and disappearance of the myelin sheath in the hippocampus of rats even at $50 \mu\text{W} / \text{cm}^2$. Frey (1988) inhibited aggressive behavior in rats at $50 \mu\text{W} / \text{cm}^2$, and modified stereotypic behavior at $8 \mu\text{W} / \text{cm}^2$. Certain odors modified this last effect. $200 \mu\text{W} / \text{cm}^2$ enhanced the narcotic effect of morphine.

Kunjilwar and Behari (1993) measured a significant decrease in acetylcholinesterase activity in the brain of rats after exposure to several frequencies of modulated radio waves at $250 \mu\text{W} / \text{cm}^2$ for 3 hours a day for a month.

Tarricone et al. (1993) exposed quail embryo cells to 10.75 GHz waves at a few $\mu\text{W} / \text{cm}^2$, and demonstrated changes in the acetylcholine receptor channels.

Chizhenkova and Safroshkina (1993) exposed rabbits to 800 MHz continuous waves for one minute while monitoring cortical neuron activity in the brain. $100\text{-}500 \mu\text{W} / \text{cm}^2$ decreased the frequency of spike bursts, and increased the number of spikes in a burst of neuronal discharges.

Kolomytkin (1994) showed that a 5-minute exposure of rats to 915 MHz waves modulated at 16 Hz increased the excitation of the brain by increasing the binding of glutamate and decreasing the binding of GABA to synaptic membranes. This occurred at less than $50 \mu\text{W} / \text{cm}^2$.

Navakatikian and Tomashevskaya (1994) exposed rats to 3000 MHz pulsed radiation. Half an hour of exposure to $10 \mu\text{W} / \text{cm}^2$ stimulated conditioned behavior, while 12 hours inhibited the behavior.

Epidemiological studies.

Chiang et al. (1989) surveyed 1170 people living and working near radio antennas and radar installations in China. Those exposed to more than $10 \mu\text{W} / \text{cm}^2$ scored worse on a memory test, and had increased visual reaction time, compared to unexposed controls.

In the early 1990s, the Swiss government commissioned a survey of 215 people living near a short wave transmitter (Abelin et al., 1995). They kept diaries. Those living less than 1.5 kilometers from the transmitter had more sleeping problems, headaches, tiredness, irritability, low-back ache and limb pain than those living over 4 kilometers away. Fewer children were promoted from primary to secondary schools. Sleep disorders were correlated with distance from the station, and improved one day after a shutdown of the transmitter. Average exposure levels were as little as $54 \text{nW} / \text{cm}^2$ ($.054 \mu\text{W} / \text{cm}^2$).

An ongoing study near a radar station in Skrunda, Latvia (Kolodynski and Kolodynska 1996) has found impaired motor function, reaction time, memory and attention among school children who live in exposed areas as compared with those who live in unexposed areas. 966 children have been tested. Levels of exposure are generally below $0.1 \mu\text{W} / \text{cm}^2$ and at no homes does the power density exceed $10 \mu\text{W} / \text{cm}^2$.

Other reviews of nervous system effects can be found in Frey (1965, 1994), Marha (1969, 1971), Healer (1969), Dodge (1969), Bawin and Medici (1973), Gordon et al. (1974), Baranski and Czernski (1976), Solon (1979), McRee (1979, 1980), Huai (1981), Medici (1982), Glaser and Dodge (1982), Ray and Behari (1990), and Kunjilwar and Behari (1993).

2. The heart

Radiation sickness typically causes bradycardia (slow heartbeat) and hypotension (low blood pressure), which are warning signs. Orlova (1960) describes other typical symptoms: tingling in the region of the heart, palpitations, stabbing pains in the heart region, and shortness of breath after exertion. Other physical findings may include an increase in the limits of the heart to the left, thudding sounds, systolic murmurs, and changes in the EKG: bradycardia or tachycardia, sinus arrhythmia, lengthened conduction, and decrease in spike amplitudes, especially in a stress test. In a clinical study of 525 workers, this researcher found cardiac symptoms in 22.3% of even the least exposed group, compared to 10% of unexposed controls. Objective cardiac changes were found in 18-35%, depending on length of time worked, compared to 9% of unexposed workers.

Other authors report similar findings. See Dodge (1969) for a review. Bachurin (1979), on EKG, found left axis deviation, sinus tachycardia or bradycardia, disturbances of intraventricular conduction, and signs of myocardial hypoxia.

Zmyslony et al. (1996) found that AM broadcast workers had six times the risk for EKG disturbances compared to radio link station workers not exposed to radio waves.

Baranski and Czernski (1976) note a change in the velocity of the pulse wave.

Huai (1981) found hypotension gave way to hypertension after 3-6 years of exposure.

Sadchikova (1960, 1974, 1980) also found a weakening of the orthostatic reflex. In advanced stages of the disease there were crises of cerebral and coronary insufficiency, and the clinical picture of ischaemic heart disease and hypertension developed.

Animal studies.

Levitina (1966) irradiated live frogs with 12.5 cm continuous waves at an intensity of 30-60 $\mu\text{W} / \text{cm}^2$. Illuminating the frog's back slowed its heart rate in most cases, while illuminating only the back of its head quickened its heart rate. When the frog was anesthetized, no effect was found. Similar results were found in experiments done previously at higher intensities in rabbits (Presman and Levitina 1962a,b).

Serkyuk exposed rabbits to 2375 MHz waves for 60 days. Exposure to 0.06 $\mu\text{W} / \text{cm}^2$ caused slowing of the heart rate and changes in the EKG (McRee 1980).

Frey and Seifert (1968) showed that the heart is most vulnerable to microwaves at particular times during its rhythm. They illuminated frog hearts with pulsed 1425 MHz waves at an average power density of 0.6 $\mu\text{W} / \text{cm}^2$. When the heart was illuminated with a pulse 200 milliseconds after the P wave, the beat rate increased. In half the cases arrhythmias occurred.

Occasionally the heart stopped. Later experiments found a similar effect with live frogs at 3 $\mu\text{W} / \text{cm}^2$ (Frey 1988). See Frey (1988) for a good review of other research.

3. Cancer

Good research on microwave cancer is sparser but fairly conclusive.

Guy and Kung exposed 200 rats to pulsed 2450 MHz waves at $480 \mu\text{W} / \text{cm}^2$ for 23 hours a day. They developed two and a half times as many cancers over their lifetime under normal life conditions as 200 unexposed controls (discussed in Frey 1994 and Szmigielski 1989a,b).

Balcer-Kubiczek (1994) proved microwaves are carcinogenic by using the C3H / 10T1 / 2 mouse embryo cell line. This cell line is frequently used in cancer research to identify chemical carcinogens. 2450 MHz pulsed waves were used. When irradiation was followed by treatment with a known tumor promoter, TPA, it caused cancers in a dose-response relationship, similar to that seen with ionizing radiation. TPA by itself did not cause any tumors. This author concludes that "2.45 GHz microwaves seem to act as an initiator or carcinogen, rather than as a promoter of malignant transformation" (p. 150). $0.1 \text{ W} / \text{kg}$ was effective.

Several epidemiological surveys have been combined with field measurements of radiation levels. In Honolulu, which has the highest radiation levels of any U.S. urban area (Microwave News, Jan./Feb. 1985), the State Health Department compared the cancer incidence of nine census tracts that include broadcast towers with that of two demographically similar tracts that do not. The U.S. Environmental Protection Agency measured radiofrequency intensities, which were below $100 \mu\text{W} / \text{cm}^2$ almost everywhere in the exposed tracts. Cancer, and especially leukemia, was significantly more common in the tracts with towers (Goldsmith 1995, 1996, Marino 1988).

Hocking and Gordon (1995) report on a similar study in Sydney, Australia. They compared cancer incidence and mortality from 1972-1990 in six northern Sydney municipalities, three of which immediately surround transmitters for 4 TV stations and an FM radio station, and three of which are more distant. Exposed children had double the rate of leukemia compared to children in the unexposed communities. Radio wave intensity was $0.2\text{-}8.0 \mu\text{W} / \text{cm}^2$ near the towers, and $0.02 \mu\text{W} / \text{cm}^2$ in the distant communities.

Dr. William Morton of the University of Oregon's Health Sciences Center in Portland has found similar trends in his study of cancer and broadcast radiation in Portland, where levels in excess of $100 \mu\text{W} / \text{cm}^2$ occur in some public areas and in private homes (Marino 1988, Microwave News, Nov./Dec. 1995).

Szmigielski (1996) did a controlled retrospective study of cancer incidence in all Polish military career personnel from 1971 to 1985. This included on average 128,000 persons per year. Personnel exposed to microwaves (generally less than $200 \mu\text{W} / \text{cm}^2$) had more than double the cancer rate of everybody else. Leukemia was more than eight times as common.

For reviews of other research, see Frey (1994), Szmigielski (1988, 1989a,b), Savitz (1987), and Goldsmith (1995, 1996).

4. Reproduction

Even extremely low levels of microwaves can cause miscarriage, altered sex ratios, birth defects, and other effects on reproduction.

Ouellet-Hellstrom and Stewart (1993) did a case-control study of over 6600 pregnancies among female members of the American Physical Therapy Association. Those who administered microwave diathermy in the six months prior to or during their pregnancy had more than three times as many early miscarriages as unexposed therapists. The risk increased with increasing numbers of exposures.

Huai (1979) found abnormal menstruation three times as often in microwave-exposed workers as in unexposed workers.

The ongoing study in Latvia has found up to 25% fewer boys in certain school grades in the area that has been exposed to the radar since 1971 (Kolodynski and Kolodynska 1996).

Navakatikian and Tomashevskaya (1994) found a decrease in testosterone in rats exposed to pulsed or continuous 2450 MHz waves at an intensity of $100 \mu\text{W} / \text{cm}^2$. They review a study by Mikolaichyk which found changes in FSH and LH in the hypothalamus of rats from a single exposure to $10 \mu\text{W} / \text{cm}^2$.

Krueger and Giarola (1975) exposed laying hens to 260 MHz waves for 16 weeks at an intensity of 5-125 $\mu\text{W} / \text{cm}^2$. Egg production was 20% less, a greater percentage of females were hatched, and egg shell quality deteriorated.

Bigu Del Blanco et al. (1973) found a 14% increase in egg production by hens exposed to continuous 7 GHz waves at 1-400 $\mu\text{W} / \text{cm}^2$. The mortality rate of the irradiated chickens also doubled.

Kondra et al. (1970) found that 6 GHz continuous waves stimulated ovulation in hens at an intensity of 0.02 pW / cm^2 (0.00000002 $\mu\text{W} / \text{cm}^2$!). Hens that were so treated from birth showed significantly higher egg production during their egg-laying life, and significantly lower egg weight than the untreated birds. This experiment was designed to simulate the exposure at ground level to the Canadian population from a typical microwave relay tower. It was conducted in Manitoba in the late 1960s. Most places on earth have higher ambient microwave levels than that now.

A later experiment by the same authors (Kondra et al. 1972) did not appear to confirm these findings, but an examination of the data reveals that the chicks in the second experiment were kept in the light 24 hours a day for the first three weeks of their lives, and that continuous lighting stimulated ovulation to approximately the same extent as the very low levels of micro-waves.

These experiments are food for thought for anyone who wonders why twentieth century human females are ovulating at ever earlier ages.

Tofani et al. (1986) exposed pregnant rats to 27.12 MHz continuous waves at an intensity of 100 $\mu\text{W} / \text{cm}^2$. Half of the pregnancies miscarried before the twentieth day of gestation, compared to only a 6% miscarriage rate in unexposed controls. 38% of the viable fetuses had incomplete skull formation, compared to less than 6% of the controls. There was also a change in the sex ratio, with more males born to rats that had been irradiated from the time of conception.

Il'chevich and Gorodetskaya report that 10 $\mu\text{W} / \text{cm}^2$ decreased litter size in mice and increased the number of stillborns (McRee 1980).

Gordon (1974) reviews other similar research in the former Soviet Union.

5. Genetic Disease

Garaj-Vrhovac et al. (1987) found chromosome breaks, fragments and deletions in up to 13% of cultured lymphocytes of 50 workers operating microwave equipment. Unexposed workers did not have these types of lesions. These researchers write that microwave radiation is "a known mutagenic agent . . . Its damaging effects on the living organism are well known" (Garaj-Vrhovac et al. 1991).

At Skrunđa, Balode et al. (1996) have found chromosome damage in cows grazing in the radiation zone. Micronuclei were counted in the red blood cells. Six times as many micro-nuclei were found compared to nearby cows unexposed to the radar.

Ockerman has found chromosome damage in 16 electrically sensitive people in a study not yet published (Kauppi 1996).

Goldsmith (1995) reports that significant chromosomal abnormalities were found in the blood of half the U.S. Embassy workers in Moscow in 1966. The irradiation of the embassy caused concern at official levels, and the health of these workers was monitored as part of a classified study called Project Pandora. The chromosomal and other findings, including evidence of increased rates of cancer, have since been declassified under the Freedom of Information Act.

Manikowska-Czerska, Czerski and Leach, at the U.S. Public Health Service in Rockville, Maryland, irradiated mice for 30 minutes a day for 2 weeks at an intensity of about 250 $\mu\text{W} / \text{cm}^2$ at various frequencies (Lerner 1984, reporting on a meeting of the Bioelectromagnetics Society). Chromosomal defects were induced in 7.2% of the sperm precursor cells, compared with .05-.07% in unexposed mice.

This is not a dose-response phenomenon. Chromosomal damage occurred at the same rate, or even less often, at much higher intensities. Mays Swicord, at the same meeting, presented evidence that DNA could absorb 400 times as much energy from microwaves as water due to molecular resonance (see Sagripanti and Swicord 1986).

Kapustin et al. found chromosome damage in the bone marrow of rats exposed to 12-cm waves at an intensity of $50 \mu\text{W} / \text{cm}^2$ for 7 hours a day for 10 days (McRee 1980).

Belyaev et al. (1992) found that 41 and 51 GHz waves at an intensity of $1 \mu\text{W} / \text{cm}^2$ suppressed repair of X-ray damaged chromosomes in *E. Coli*. One 5-minute exposure to the microwaves prevented repair for the hour and a half of the incubation experiment. At $0.1 \mu\text{W} / \text{cm}^2$ the effect was less pronounced.

Lai and Singh (1995) found chromosome breaks in rat brain cells at higher intensities than I am reporting on elsewhere ($1\text{-}2 \text{ mW} / \text{cm}^2$), but these experiments are significant in finding chromosome breaks immediately upon exposure. Sarkar (1994) also found significant chromosome damage in the testes and brain of mice at these intensities.

Akoyov (1980) reported that the dose necessary to damage chromosomes was significantly smaller in live animals than in cell cultures.

A review of earlier research can be found in Heller (1969).

6. Effects on growth and aging

Numerous researchers have found adverse effects of various frequencies of microwaves on animal growth. Giarola et al. (1971, 1973) found $14\text{-}500 \mu\text{W} / \text{cm}^2$ depressed the growth of chickens and baby rats. Gabovich et al. (1979) obtained a similar result with young rats at $100 \mu\text{W} / \text{cm}^2$, as did Ray and Behari (1991) at $600 \mu\text{W} / \text{cm}^2$. Gabovich (1979) reported reduced weight increase in pregnant rats at $100 \mu\text{W} / \text{cm}^2$. Bigu Del Blanco et al. doubled the mortality of chickens at less than $400 \mu\text{W} / \text{cm}^2$. And Garaj-Vrhovac et al. (1991) found only 60% of the normal number of Chinese hamster cells after exposing the culture to $500 \mu\text{W} / \text{cm}^2$ for 60 minutes.

The evidence on plants is startling:

Trees growing in pine forests exposed to the Skrunda radar have had decreased thickness of growth rings beginning after 1970, which coincided with the start of operation of the radar. Nearby unexposed trees have not been similarly affected (Balodis et al. 1996).

Study of pine needles and cones at Skrunda has revealed accelerated resin production and premature aging of pine trees in the exposed area, even where the intensity is only $24 \text{ pW} / \text{cm}^2$ ($0.000024 \mu\text{W} / \text{cm}^2$), as compared with trees in nearby unexposed areas. Also, the germination of low exposure seeds is enhanced, while the germination of higher exposure seeds is severely impaired. The authors have noted a similarity to the effects of ultraviolet radiation (Selga and Selga 1996).

Duckweed plants grown near the Skrunda radar have a shorter life span and impaired reproduction compared to plants grown distant from the radar. Morphological and developmental abnormalities are also found in the exposed plants (Magone 1996).

Marha (1969) writes, "It is known from reports in the literature that the velocity of cell division with *Vicius fabus* [a bean] is accelerated at field intensities of $10\text{-}4 \text{ V} / \text{m}$ at frequencies of approximately 30 MHz and the velocity decreases at values above $0.1 \text{ V} / \text{m}$ " (p. 189). $10\text{-}4 \text{ V} / \text{m}$ corresponds to a power density of $0.0026 \text{ pW} / \text{cm}^2$ ($0.000000026 \mu\text{W} / \text{cm}^2$). This is less than what we receive on earth from satellites. These experimental results, and those from Skrunda, and those of Kondra with chickens, above, prove that satellite signals are biologically active.

7. The blood and immune system

Blood cells.

The immune response is often biphasic: stimulated at low intensities and inhibited at higher intensities.

Chiang et al. (1989) in their epidemiological study found that white blood cell phagocytosis was stimulated by chronic exposure to the lowest intensities of radio waves and inhibited, sometimes severely, by higher intensities. The subjects were students in kindergarten, secondary school, and college who were exposed to radio transmitters or radar installations at school. Exposure levels ranged from 0-4 $\mu\text{W} / \text{cm}^2$ to 120 $\mu\text{W} / \text{cm}^2$.

Goldoni (1990) examined air traffic controllers at a two year interval and found, in almost all cases, a significant decrease in white blood cells and platelets during their two years on the job. White blood cell count was below normal after two years in 36% of the workers. Red blood cell counts were lower on average than the control group and sometimes sub-normal.

Huai (1981) also found an average decrease in white cells and platelets among microwave workers.

Sadchikova (1974) found changes in the same directions in 1180 workers.

Near the Skrunda radar, the 230 people examined had significant increases in their white cell counts and alterations in differential counts. Children were most affected. The irradiated Moscow embassy workers had an increased hematocrit, a strikingly higher white cell count and other changes that progressed during the time of their exposure (Goldsmith 1995).

Zalyubovskaya and Kiselev observed 72 microwave-exposed engineers and technicians over a period of 3 years. Their exposure level occasionally reached 1000 $\mu\text{W} / \text{cm}^2$.

During the 3 years, red blood cells and hemoglobin content of the blood declined, reticulocytes and platelets were reduced, white blood cells dropped to 30% below the control group, and lymphocytes increased 25%. The number of bacteria in the mouth was considerably higher and the bactericidal activity of the skin was less. These and other changes in immune function were then confirmed by experiments on mice. The animals were exposed to comparable intensities as the workers for 15 minutes a day for 20 days. The mice also developed 1/3 to 1/2 fewer antibodies in the blood, had lower resistance to infection, and a decrease in the size of their thymus, spleen, and lymph nodes.

Zalyubovskaya and Kiselev also noted an 18% decrease in the osmotic resistance of red blood cells and a 26% decrease in their acid resistance, in the exposed workers. This brittleness of red blood cells upon exposure to electromagnetic fields has been noted by others (Dodge 1969, Sadchikova 1974) and recently confirmed by Ockerman (Södergren 1996, Kauppi 1996).

Lysina wrote that basophilic granularity of erythrocytes should be taken as an early sign of microwave effect on the human organism (Dodge 1969, p. 145).

Bachurin (1979) found that chronic exposure to 20-60 $\mu\text{W} / \text{cm}^2$ increased the frequency of influenza, tonsillitis and other illnesses among workers.

See Drogichina (1960), Sokolov and Arieovich (1960), and Dodge (1969) for a review of other clinical studies showing similar changes in the blood elements.

Shandala et al. (1979) found that 2375 MHz at 500 $\mu\text{W} / \text{cm}^2$ caused a sudden significant impairment of immune function in rabbits. Animals exposed for 7 hours a day for 3 months did not recover normal immune function for 6 months afterwards. At 10 and 50 $\mu\text{W} / \text{cm}^2$ immunity was stimulated.

These results were further refined by a 30-day experiment with guinea pigs at 1, 5, 10, and 50 $\mu\text{W} / \text{cm}^2$ (Shandala and Vinogradov 1978). All these intensities increased complement in the blood and stimulated phagocytosis by neutrophils, but 1 $\mu\text{W}/\text{cm}^2$ had the biggest effect, and 50 $\mu\text{W} / \text{cm}^2$ the smallest effect. Two months later the animals that had been exposed to 10 and 50 $\mu\text{W} / \text{cm}^2$ had an impaired response to hypoxia, and to injection of foreign protein.

These researchers also established that at 50 $\mu\text{W}/\text{cm}^2$ the radiation promotes autoimmunity by altering the antigenic structure of tissue and serum proteins. This was confirmed by Gabovich et al. (1979).

Other similar work has been done by Shutenko et al. (1981), Veyret et al. (1991), Ray and Behari (1990), Shandala and Vinogradov (1983), Chou and Guy (Lerner 1984, p. 64), and Marino (1988). Dumanskij and Shandala (1974) noted effects even at 0.06 $\mu\text{W}/\text{cm}^2$. Elekes et al. (1994) found an increase in antibody-producing cells in the spleen of mice at 30 $\mu\text{W}/\text{cm}^2$ and noted the relevance of their study to mobile communications.

Blood sugar.

Out of 27 exposed workers, 7 had flat blood sugar curves, 7 were prediabetic, and 4 had sugar in their urine (Bartonicek et al., summarized in Dodge 1969). Gel'fon and Sadchikova (1960), Sadchikova (1974), and Sikorski and Bielski (1996) report similar findings. Klimkova-Deutschova (1974) found a slight increase in the fasting blood sugar in 74% of workers.

These reports are consistent with animal experiments showing disturbed carbohydrate metabolism. Dumanskij and Shandala (1974), at 0.06-10 $\mu\text{W}/\text{cm}^2$, found decreased mitochondrial activity of cytochrome oxidase, decreased glycogen in the liver, and accumulation of lactic acid. This pattern has been confirmed by later experiments (Dumanskiy 1976, 1978, 1982a,b) and by other researchers (Gabovich et al. 1979, Belokrinitskiy 1982, 1983, Shutenko et al. 1981, Dodge 1969).

Navakatikian and Tomashevskaya (1994), at 100 $\mu\text{W}/\text{cm}^2$, report decreased serum insulin in rats.

Cholesterol and triglycerides.

Microwaves caused an elevation in blood cholesterol in 40.9% of exposed workers vs. 9.5% of controls, in agreement with reports by other researchers.

Beta-lipoproteins were also elevated. (Klimkova-Deutschova 1974).

Sadchikova et al. (1980) found elevated triglycerides in 63.6% of exposed workers and elevated beta-lipoproteins in 50.2%. A direct relationship was found between hyperbetalipoproteinemia and retinal angiopathy. Higher cholesterol and phospholipids were also found in the exposed workers compared to the controls.

Serum proteins.

Changes in serum proteins have been noted by many in clinical studies. It is found that microwaves cause an increase in total blood proteins and a decrease in the albumin-globulin ratio. See Pazderova et al. (1974), Sadchikova (1974), Klimkova-Deutschova (1974), Dodge (1969), Gel'fon and Sadchikova (1960). Drogichina (1960) writes that these are signs of the early influence of microwaves, before clinical signs of disease are evident.

Other biochemistry.

Gabovich's rats (1979) had elevated ascorbic acid in their urine and adrenals.

Dumanskiy and Tomashevskaya's rats (1982a,b) had elevated blood serum urea and residual nitrogen from exposure to 8 mm or 3 cm waves at 60 $\mu\text{W}/\text{cm}^2$. This reflected disturbed protein metabolism. Gabovich's findings of high ascorbic acid in the adrenals was also confirmed.

8. Cataracts

In the early 1970s the U.S. Army undertook an ophthalmological study of employees at Fort Monmouth, New Jersey, a facility where electronic communication, detection, and guidance equipment are tested, developed and used. Workers exposed to microwaves had substantially more lens opacities than the controls (Frey 1985).

Huai (1979) found more lens vacuoles in irradiated workers than in controls. The tendency was evident even in those exposed to less than $200 \mu\text{W} / \text{cm}^2$, and became statistically significant at higher intensities. A few cases of cataracts were found in the microwave workers.

Bachurin (1979) noted a greater incidence of points of turbidity of the lens, narrowing of the arteries, spasm of vessels, and beginning sclerosis and angiopathy of the retina. These were young men working in TV and radio installations and other facilities where microwave intensities fluctuated between 20 and $60 \mu\text{W} / \text{cm}^2$, only occasionally reaching $100 \mu\text{W} / \text{cm}^2$.

Sadchikova (1974) and Sadchikova et al. (1980) noted angiopathy or sclerosis of retinal blood vessels in workers exposed to several hundred $\mu\text{W} / \text{cm}^2$ in radar production shops.

Drogichina (1960), 20 years previously, had noted both angiopathy of the retina and opacifications of the lens in microwave workers.

In 1969 Zaret studied 736 radar workers and 559 controls, and found significantly more lens opacities in the radar workers. Belova's study of 370 microwave workers, Majewska's study of 200 microwave workers, and Janiszewski and Szymanczyk's study at the Institute of Aviation Medicine in Warsaw all yielded similar results. Zydecki found an increased frequency of lens opacities in 3000 microwave workers who were never exposed to thermal intensities and concluded that microwaves prematurely age the lens. Baranski and Czernski, reviewing this study (1974), stress that "the statistical treatment of data is extremely careful and does not leave room for doubts" (p. 167).

9. Internal organs

The thyroid gland is one of the most sensitive indicators of microwave influence. Animal experiments show increased activity and/ or enlargement of the thyroid at $153 \mu\text{W} / \text{cm}^2$ (Demokidova 1973), at $100 \mu\text{W} / \text{cm}^2$ (Gabovich et al. 1979, Navakatikian and Tomashevskaya 1994), and at $1 \mu\text{W} / \text{cm}^2$ (Dumanskiy and Shandala 1974). Several clinical studies confirm this (Drogichina 1960, Sadchikova 1960, Smirnova and Sadchikova 1960, Baranski 1976). Smirnova states that physiological and even pathological changes in the activity of the thyroid can be detected long before any clinical manifestations of microwave injury. In this study 35 out of 50 persons working with microwave equipment showed abnormal thyroid activity. Drogichina reports increased thyroid activity in almost all microwave workers examined.

The adrenals are also extremely sensitive to radiation. In animals irradiated for from 2 months up to 2 years, the adrenals are generally enlarged, have an altered ascorbic acid content, increase the secretion of adrenaline and glucocorticoids, and decrease the secretion of testosterone: Chou and Guy at $500 \mu\text{W} / \text{cm}^2$ (Lerner 1984), Navakatikian and Tomashevskaya (1994) at $100 \mu\text{W} / \text{cm}^2$, Gabovich et al. (1979) at $100 \mu\text{W} / \text{cm}^2$, Dumanskiy et al. (1982) at $25 \mu\text{W} / \text{cm}^2$, Shutenko et al. (1981) at $10 \mu\text{W}/\text{cm}^2$, Dumanskiy and Shandala (1974) at $0.06 \mu\text{W} / \text{cm}^2$. With a shorter exposure, Giarola et al. (1971) found a decrease in the mass of the adrenals in chickens at $14\text{-}24 \mu\text{W} / \text{cm}^2$. In clinical studies, Sadchikova (1974) noted altered excretion of epinephrine and norepinephrine; Kolesnik et al. noted a decreased blood 17-CHS response to ACTH injection in all 35 workers tested (Baranski and Czernski 1976); Hasik, and also Presman, noted increased activity of the adrenal cortex (Dodge 1969).

Ray and Behari (1990) found a significant decrease in the weight of the spleen, kidney, brain and ovary, and an increase in testicular weight in young rats exposed to 7.5 GHz, $600 \mu\text{W} / \text{cm}^2$, 3 hours a day for 60 days.

Dumanskiy and Shandala (1974) found increased RNA and DNA in the liver and spleen, and structural changes in the liver, spleen, testes, and brain of white rats and rabbits exposed to 3 cm and 12 cm waves at 0.06 to $101 \mu\text{W} / \text{cm}^2$ for 8 to 12 hours a day for 180 days.

Giarola et al. (1971, 1973) report an enlarged spleen and thymus in baby rats exposed for 35-53 days to 880 MHz, $14 \mu\text{W} / \text{cm}^2$.

Erin' (1979) reports a 23-83% increase in oxygen tension in renal tissues of adult white rats exposed to 2375 MHz, 50 $\mu\text{W} / \text{cm}^2$ for 1-10 days.

Belokrinitskiy (1982) observed changes in the biochemistry and ultrastructure of liver, heart, kidney and brain tissue in rats exposed to 12.6 cm waves at intensities of 5 $\mu\text{W} / \text{cm}^2$ and higher for up to 2 months.

50 W / cm^2 for 7 hours a day for 10 days caused urine output to fall 15%, and 500 $\mu\text{W} / \text{cm}^2$ once for 7 hours had a larger effect (Belokrinitskiy and Grin' 1983). Elevation of urine pH, protein in the urine, and changes in electrolyte excretion persisted up to 25 days after exposure. Examination of kidney tissue revealed vasodilation, endothelial breakdown, perivascular and pericellular infiltrations, hemorrhage, swelling, partial de-epithelialization along the nephron, and other changes. Histochemical analysis showed decreased cellular glycogen, changes in RNA and DNA concentration, and the appearance of neutral fat droplets. Some of these changes were irreversible, even two months after one 7-hour exposure.

In large clinical studies, Orlova (1960) noted decreased appetite, indigestion, epigastric pain, and enlargement of the liver in irradiated workers, while Gel'fon and Sadchikova (1960) also noted liver enlargement and tenderness in certain patients, with a decreased antitoxic function of the liver in a few. Trinos (1982) noted decreased appetite and indigestion, as well as chronic gastritis, cholecystitis, and decreased gastric acidity, especially in workers exposed to microwaves for more than ten years. Bachurin (1979) also noted chronic gastritis and cholecystitis in workers occupationally exposed to 20-100 $\mu\text{W} / \text{cm}^2$.

10. Lungs

Shortness of breath has already been mentioned as part of radiation sickness and is probably cardiac related. The ongoing study in Skrunda has also revealed a decreased pulmonary function in exposed children (Levitt 1995). And an experiment with rats (Gabovich et al. 1979) revealed 7.7% decreased oxygen consumption during a 10-week exposure to 2375 MHz at 100 $\mu\text{W} / \text{cm}^2$. See the discussion of hypoxia, below, under "Mechanisms".

11. Bone marrow

Kapustin et al. found chromosome damage in the bone marrow of albino rats at 50 $\mu\text{W} / \text{cm}^2$, as was discussed previously. The damage was higher 2 weeks after irradiation than immediately (McRee 1980).

Sadchikova (1974) found signs of stimulated erythropoiesis in the bone marrow of young men occupationally exposed to microwaves. So did Sevast'yanova and Vilenskaya in animal experiments with millimeter waves, which penetrate less than 1 mm into the body and do not reach the bone marrow (Akoyev 1980).

12. Hair and nails

Radiation sickness also causes hair loss and brittle finger-nails (Dodge 1969, Inglis 1970, Huai 1979).

13. Synergistic effects

Low intensity microwave radiation increases the effects of morphine (Frey 1994).

It modifies the effects of lithium (Frey 1994).

It increases the effects of Haldol (Frey 1994).

It counteracts the effects of amphetamine (Frey 1994).

It increases the toxicity of formaldehyde and carbon monoxide. Formaldehyde and carbon monoxide increase the sensitivity of the body to microwaves (Shandala and Vinogradov 1978).

It increases the toxicity of Cardiazole (Baranski and Czernski 1976, pp. 163-4).

High temperatures or hypoxia increase sensitivity to microwaves (Baranski and Czernski 1976, p. 75).

14. Microwave hearing, and other sensing

"The perceptibility of radiofrequency fields is the most thoroughly established datum in the behavioral literature on such radiations" (Justeson 1979, pp. 1061-2). Pulsed micro-waves can be heard by most individuals as buzzes, hisses, chirps, pops, or clicks, provided the pulses have sufficient peak energy. The average power density need be only 2 or 3 $\mu\text{W} / \text{cm}^2$. Peak power goes totally unregulated by industry or government, and even the voluntary standard "is well above the threshold for auditory effect" (IEEE 1991, pp. 33-34). Since virtually all cellular broadcasts are soon to be digital and pulsed, we may expect this sort of chronic nuisance to become much more widespread. Auditory sensitivity to microwaves varies enormously; already there have been reports of suicides by extremely sensitive individuals. This author is among those who hear electromagnetic radiation at present ambient levels.

The presently accepted explanation for this phenomenon is that pulsed radiation creates thermoacoustic pressure waves in your brain. These pressure waves reach your inner ear where the vibrations are heard like any other sound. Thus the assumption that microwaves will not harm you if they aren't strong enough to cook you has taken a strange twist. But more on that later.

For extensive reading about the microwave hearing phenomenon, see Frey (1963, 1969, 1971, 1973, 1988), Olsen (1980), Olsen and Hammer (1980), Justeson (1979), Wieske (1963), and the book by Lin (1978).

Frey and co-workers also demonstrated that animals will avoid pulsed microwaves when they are able to do so. In one experiment rats spent only 30% of their time in the illuminated half of their box and 70% of their time in the shielded half. The frequency was 1.2 GHz, average power 200 $\mu\text{W} / \text{cm}^2$ and peak power 2.1 mW / cm^2 (Frey and Feld 1975, Frey, Feld and Frey 1975). Frey also demonstrated avoidance of microwaves by cats (Frey 1969, Frey and Feld 1975).

At relatively high intensities at 10 and 16 GHz, Tanner et al. (1966, 1967, 1970) found that chickens, pigeons, and seagulls showed great distress and collapsed within a few seconds. Intrigued by the fact that birds reacted this way when irradiated from above and not from below, and by the fact that defeathered hens showed no such distress, these authors postulated that feathers serve as dielectric aerials in the micro-wave region. They subsequently designed experiments which proved that bird feathers indeed make fine receiving aerials for 10 GHz waves (Bigu Del Blanco et al. 1973). Their work has serious implications, because virtually all radars, television and radio antennas, and wireless communication transmitters are aimed above the horizon where the birds fly. The microwave density increases with height, and must cause enormous suffering. There have been many anecdotal reports of birds leaving the area after a cellular tower goes into operation (Hawk 1996).

Finally, in a study of anteaters, Kholodov reports that they lost their ability to "inform" other anteaters about a food source during microwave irradiation, and furthermore that they oriented their snouts along a particular axis during the irradiation. Power levels were not stated (Inglis 1970).

15. Electrical sensitivity (ES)

Electrical sensitivity is a new name for radiation sickness, so-called because many sufferers become aware that electromagnetic fields make them ill and they experience symptoms immediately upon exposure. For many, including this author, it is like developing a new sense. Sensitivity may develop to any type of radiation including that from power lines, microwaves, X-rays, and radioactivity. Modern society may become intolerable and even ordinary sunlight may cause illness. The degree and range of

sensitization depend on both the source of the injury and the susceptibility of the individual. Baranski and Czernski (1976) write, "In certain instances syndromes of neurological disturbances (without organic

lesions) and signs of neurosis, accompanied by a poorly expressed bioelectric function of the brain, are found in microwave workers following long periods of exposure. These patients may be incapacitated for further work and even normal everyday life" (p. 164).

In a controlled double blind clinical study, Rea et al. (1991) proved that electrically sensitive patients could perceive low level radiation. These researchers used 0.1 Hz to 5 MHz magnetic fields with a field strength of 70-2900 nT.

Ockerman compared 16 electrically sensitive patients with 10 healthy volunteers, and demonstrated clear differences in the red and white blood cells and urine, as well as chromosome damage, in the electrically injured group (Kauppi 1996, Södergren 1996).

Johansson and Liu (1984) found specific changes in the skin of electrically sensitive patients: remarkably high numbers of somatostatin immunoreactive dendritic cells and histamine positive mast cells.

Huai (1981) writes that "those syndromes are not easy to recover" (p. 636).

It has been estimated from limited survey data that 2% of the population is susceptible to becoming electrically sensitive (Firstenberg 1996). This estimate comes partly from medical statistics on porphyria, which is prevalent in the electrically injured (see below). In agreement with this figure, Sadchikova (1960) reported that 11 of 525 people, or about 2%, had to cease working under conditions of microwave influence.

A higher estimate of 15% comes from a survey of 731 employees at 5 Swedish workplaces (Knave 1992). The source of radiation here is video display terminals. The 15% figure also receives support from earlier research. Sadchikova (1960) reported that radiation sickness had arisen after 3 years of work in 15% of employees, and in later work (1974) the same author writes that its frequency "did not exceed 15%." Klimkova-Deutschova (1974) found synchronized activity on the EEG in 14.3% of workers at a radio transmitting station.

It may be supposed from the above data that 15% of people exposed to microwave radiation develop overt symptoms, and that in 2% the changes become irreversible.

In controlled clinical experiments, Leitgeb (1994) found 2.3% of a random population in Graz, Austria were hypersensitive to electric currents, and Szuba and Szmigielski (1994) found 2 out of 71 healthy volunteers were hypersensitive to power line radiation, as evidenced by a marked delay in auditory and visual reaction time. Hanson (1995) found electromagnetic hypersensitivity in 12 of 519 dental patients, again a 2.3% rate. In 1981 Cabanes and Gary found 3 of 75 healthy male volunteers were able to perceive extremely low exposures to power line radiation (reviewed by Szuba and Szmigielski).

There are animal models for ES. Salford et al. (1993), testing for carcinogenicity of microwaves in rats (915 MHz, specific absorption rate of .0077-1.67 W / kg), noted that "for some modulation frequencies the average tumor size in the exposed animals largely exceeds the average size in the controls ... This might indicate that in the few animals that, for some reason, are sensitive to the exposure, tumour growth is stimulated strongly" (p. 317).

Frey (1988) found that living in an electromagnetic field increased emotionality in test animals, and that "some animals were particularly sensitive to exposure to such fields" (p. 802). He also found, in other experiments, the responses to radiofrequency radiation were bimodally distributed, again calling "attention to the importance of individual differences in sensitivities when low-intensity radiofrequency radiation is used" (p. 804).

Animal sensitization has also been demonstrated. Shandala et al. (1979), in a chronic exposure experiment on rats and rabbits (2375 MHz, 10, 50 and 500 μ W / cm²), found a substantially lower threshold of skin sensitivity to electrical stimulation and a decrease in the "electronic irradiation threshold."

16. Diagnosing ES: a guide for doctors

The clinical studies reviewed in this booklet report the following early signs of radiation injury:

- (1) change in olfactory sensitivity, which (if low) a single dose of caffeine may restore to normal
- (2) increased thyroid activity and / or enlargement of the thyroid gland
- (3) elevated serum protein and globulin, and lowered albumin / globulin ratio
- (4) elevated histamine in the blood
- (5) a weakened cutaneous vascular reaction to histamine
- (6) basophilic granularity of erythrocytes
- (7) decreased osmotic and acid resistance of erythrocytes
- (8) mild leukopenia and thrombocytopenia
- (9) immunoglobulins at the lower limit of normal
- (10) bradycardia and/or hypotension
- (11) lengthening of the intraauricular and intraventricular conduction of the heart on EKG, also a decrease in the amplitude of the R and T teeth, which may show up only upon physical stress
- (12) subclinical activity on the EEG; the appearance of pointed synchronized waves of high amplitude and increase in slow (delta and theta) waves. These changes may appear only after activation by hyperventilation.
- (13) on neurological exam: tremors of the eyelids and hands, increased tendon reflexes, decreased abdominal reflexes
- (14) abnormalities in the blood sugar curve, and slight increase in the fasting blood sugar
- (15) increase in cholesterol and beta-lipoprotein
- (16) increased or decreased serum lactic acid
- (17) acrocyanosis

Södergren (1996) in his forthcoming study is expected to report on specific changes in the urine, as well as in the red and white blood cells.

In view of the expected metabolic hypoxia (see below), changes in the blood oxygen content and pH might also be sought.

Low values for red blood cell copper have also been seen in electrically sensitive patients, in accord with the expected redistribution of metals in the body (see below).

Kowalski and Indulski (1990) discuss psychological tests which detect early disorders of the central and peripheral nervous systems from exposure to electromagnetic radiation.

The full set of clinical signs and symptoms is listed in the section on radiation sickness, above.

We now have in addition the reported experiences of large numbers of people who live near recently-erected digital cellular and PCS antennas. I have prepared the following list of signs and symptoms to aid

physicians in diagnosing micro-wave radiation sickness among the general population. Some patients may have a great many of these findings; some only a few.

Physical exam

Look for:

- skin rash
- enlargement or tenderness of the thyroid
- heart rate higher than usual
- blood pressure higher than usual
- shortness of breath (may "look like" an anxiety attack)
- wheezing
- lungs not clear
- increase in the limits of the heart
- liver tenderness
- abdominal tenderness
- general hypersensitivity of the skin
- any elevation of body temperature
- sinus pain /drainage
- deterioration of the teeth / pain in teeth with metallic fillings
- acrocyanosis

Neurological:

- tremors, especially of eyelids and hands
- change in visual acuity
- decreased sensitivity to odors
- decreased sensitivity to pinprick in the hands or feet
- increased sensitivity to vibration
- increased tendon reflexes of the upper or lower extremities
- decreased abdominal reflexes
- general muscle weakness
- anisocoria

Mental:

- agitation
- fatigue
- impaired short or long term memory
- paranoia (in advanced illness)

Patient history

- Recent eye problems, especially pressure behind the eyes, but also floaters, difficulty focusing, deteriorating vision, eyeaches, etc.
- Sudden dental problems, especially broken fillings
- Dryness of the lips, mouth, skin, or eyes
- Puffy lips
- Swollen or sore throat
- Sinusitis
- Bronchitis
- Headaches
- Earaches
- "Burning" in any part of the body: chest, eyes, ears, testicles, etc.
- Pressure or pain in the chest
- Insomnia
- Dizziness
- Nausea
- Loss of appetite

Pelvic discomfort/pain in the testicles or ovaries
Paresthesias
Muscle spasms
Pain in the soles of the feet Pain in the legs
Muscular, joint, or abdominal pain, especially pains that move around the body
"Electrical currents" in any part of the body
Sweating
Itchy systemic rash
Spontaneous nosebleeds
Frequent urination
Craving for carbohydrates

Laboratory tests

Abnormal blood sugar curve
Elevated blood histamine
Elevated serum protein and globulin
Lowered albumin/ globulin ratio
Increase in cholesterol and beta-lipoprotein
Mild leukopenia or thrombocytopenia. Or any change in leucocytes (increase or decrease) or immunoglobulins, or IGG subclasses abnormal
Signs of autoimmunity
Altered serum lactic acid
Altered oxygen content or pH of the blood Increased copper or zinc in the urine
Decreased red blood cell copper
Change in appearance of red blood cells (rouleaux formation, etc.)
Increased thyroid activity
Increased adrenal activity

EKG

Lengthening of the intraauricular and intraventricular conduction.
Decrease in amplitude of the R and T teeth.
Any arrhythmias.

EEG

Seizure activity.
Abnormal excitation.

17. Mechanisms of injury

Shear-strain/closed head injury.

Finally the issue of "thermal" vs. "non-thermal" effects must now be addressed, however reluctantly. The argument has been made by industry representatives that all health effects from microwaves are only due to the excessive heating of the body. These are the same scientists who never do any experiments at low levels of power because they don't expect to find any effects, and they are the same scientists who dismiss all the effects they do find at high levels of power as being due to heating. Since funding for research is largely controlled by these same scientists (see especially Frey 1982 for an excellent account of the situation), they are running a good scam. As can be seen from the review of studies in this report, however, there is nevertheless plenty of good, consistent evidence from more objective researchers that exposes once and for all the fiction these scientists are still trying to maintain.

Even if their conclusions were true, however, their reasoning escapes me. Does a health hazard cease to exist simply because it is labeled "thermal"? "Don't worry," they seem to be trying to tell us, "these microwaves are only cooking you after all!"

But let us look at the physics of the situation. Microwaves produce heat in food and in living organisms by vibrating ions and polar molecules such as water hundreds of millions of times per second. The molecules align themselves with the rapidly alternating electromagnetic field, and the friction from the vibrations produces heat. So that in actual fact microwaves have primarily a direct electromagnetic interaction with our molecules. Heating is only a side effect.

However it is an important side effect, far more important than those scientists have admitted. Microwaves of extremely low intensity are known to cause thermoacoustic pressure waves in the head, including the brain, causing the phenomenon of microwave hearing (see above). This may cause a shear-strain injury in the brain, resulting in axonal tearing and neural degeneration, similar to what occurs in concussion from traumatic injury. Frey (1988) remarks on the similarity between the symptoms of radiation sickness / electrical sensitivity, and the symptoms of closed head injury or post-concussive syndrome: reduced attention span, impaired complex information processing, memory disturbance, increased emotional lability, irritability, anxiety, and depression. Reference to medical text-books reveals other similarities, including headache, dizziness, photophobia, respiratory distress, bradycardia, change in blood pressure, cardiac arrhythmias, pupil asymmetry, altered glucose metabolism, and increased caloric demand, all of which have been noted in radiation sickness/electrical sensitivity. Frey comments, "It is ironic that it is such a shear-strain effect in the brain that the engineers concerned with hazards were implicitly assuming when they were trying to explain away the radiofrequency hearing effect as not being an indication of hazard. They never realized that shear-strain due to thermoacoustic expansion in brain tissue would itself damage the brain" (p. 800).

Similar damage, by the same mechanism, might also be responsible for effects on other organs. I am thinking particularly of the testes, which because of their location and size absorb much more microwave radiation than other organs (Copson 1962). Dr. John Holt, for example, speculates on the connection between electromagnetic radiation and the world-wide decline in human sperm count, as well as the recent global decline and extinction of so many species of amphibians (personal communication).

Blood-brain and other barriers.

In this regard concussions have been studied experimentally in animals by the creation of pressure pulses induced by the introduction of a small volume of fluid outside the brain membranes through a hole in the skull. These low magnitude pressure waves were found to increase the permeability of the blood-brain barrier (Rinder and Olsson, described in Oscar and Hawkins 1977).

That microwaves at low power also alter the blood-brain barrier has been confirmed. Frey's rats that had avoided exposure to microwaves were also found to have increased permeability of foreign substances into their brain. This occurred after irradiation by both pulsed waves, at $200 \mu\text{W} / \text{cm}^2$, and continuous waves, at $2.4 \mu\text{W} / \text{cm}^2$.

Oscar and Hawkins (1977) verified Frey's work and took it farther, demonstrating increased uptake of even very large molecules like dextran, and observing the effect down to $30 \mu\text{W} / \text{cm}^2$ for pulsed waves and $300 \mu\text{W} / \text{cm}^2$ for continuous waves. Indeed a biphasic response was observed: uptake of mannitol into the brain increased up to a power level of $1 \text{mW} / \text{cm}^2$ and then decreased at higher intensities. A similar biphasic pattern has been seen by Bawin and Adey for calcium efflux from the brain, and by Balcer-Kubiczek (1994) for cancer from ionizing radiation. It is just such a biphasic pattern that has caused experiments at so-called "thermal" levels of exposure to be erroneously interpreted as contradicting the results of experiments done at "non-thermal" power levels.

Often erroneous interpretation results from simply failing to analyze the data. Thus Merritt et al. reported on their study purporting to show no alteration of barrier permeability from microwaves. "But a statistical analysis of the data presented in their paper by several scientists showed that, in fact, their data supported the opposite conclusion and provided a confirmation of the findings of Frey et al." (Frey 1988, p. 808).

The integrity of other barriers is also compromised by microwaves. In a blood-vitreous barrier experiment (Frey 1988) it was demonstrated that a 25-minute exposure to power densities of $75 \mu\text{W} / \text{cm}^2$ increased the uptake of sodium fluorescein dye into the vitreous humor of the eye. In this connection the work of Neelakantaswamy and Ramakrishnan indicates that radiofrequency radiation can induce bending moments and stresses in the eye tissue that may provide an explanation for cataract formation. This is the same mechanism that may cause shear-strain injury in the brain (see above).

Similar compromise of the placental barrier may be expected (Frey 1988) but experiments have not yet been done in this area at low power densities.

Calcium efflux.

As another way of measuring neurological response, it has been found that calcium ion efflux from brain tissue is exquisitely sensitive to irradiation with radiofrequency waves. This work has been done by Bawin et al. (1970), Blackman et al. (1980, 1986), Dutta et al. (1986) and Kunjilwar and Behari (1993), among others. See Frey (1988) for a review. In the most sensitive study to date, Dutta et al., at the Howard University Cancer Research Center, observed peaks in calcium efflux from human neuroblastoma cells at a specific absorption rate (SAR) of 1 and 2 mW / g, and also at .05, .0028, .001, .0007, and .0005 mW / g, with some effect all the way down to .0001 mW / g. The frequency was 915 MHz. This was obviously a resonance phenomenon that did not depend linearly on the dose. Peaks in calcium efflux and influx were observed at very specific combinations of modulation frequency, depth of modulation, power density, and exposure time. For example a 30 minute exposure at 80% depth amplitude modulation of 16Hz caused an efflux that did not return to normal levels for at least 20 minutes after the exposure ended. The effect at 0.0007 mW / g SAR was quadruple the effect at 2.0 mW / g, in other words 3000 times the intensity had 4 times less of an effect under these particular conditions.

Blackman (1986) also observed that varying the direction or the intensity of the local geomagnetic field changed the results completely. Therefore, "(1) a complete description of electromagnetic exposure conditions should include measures of frequency and intensity of electromagnetic field and direction and intensity of the local geomagnetic field; and (2) the complex interplay between frequency, intensity, and local geomagnetic field indicates that the underlying mechanism is not thermally based" (p. 44). In other words, (1) the functioning of a living organism is guided by the state of its environment; (2) perception of its environment is electromagnetic in nature; and (3) both perception and functioning are easily altered by external electromagnetic signals which, as we have seen, are some one billion times as powerful as what naturally exists.

Hypoxia.

A common theme throughout the animal studies on microwave influence is a serious disturbance in carbohydrate metabolism. In particular, microwaves inhibit cytochrome oxidase activity in the mitochondria of the brain and the liver. The result is a breakdown in oxidative phosphorylation, compensatory intensification of glycolysis, and a buildup of lactic acid in the tissues. The liver becomes depleted of glycogen, the blood sugar curve is affected, and the fasting blood glucose is raised. The patient craves carbohydrates, and the cells become oxygen starved.

It may be noted that hypoxia is also a common side effect of closed head injury, and that the primary cardiac response to hypoxia is a reflex bradycardia. Hypoxia also causes demyelination in the nervous system. Oxygen deprivation may well account for many of the symptoms of radiation sickness, including fatigue, weakness, headache, inability to think, acrocyanosis, muscular pain, and, of course, shortness of breath.

Possibly additional insight into electrical injury might be had from studying the mitochondrial myopathies.

Heavy metals.

It is known that chronic irradiation by microwaves causes a substantial redistribution of metals in the body and a consequent alteration in the activity of metalloproteins and metalloenzymes. For example, an increase in the activity of ceruloplasmin (a copper-containing globulin) and a decrease in the iron content of transferrin in the blood serum have been observed (Dumanskiy et al. 1982a,b). The lowered activity of cytochrome oxidase, a copper-containing hemoprotein, noted above, may also be relevant.

Shutenko et al. (1981) did a detailed study of the effect of radio waves on metals in the body, using 90 young and mature white rats and a generator of 2375 MHz (12.6 cm) waves. Intensities of 100 μ W / cm² and 10 μ W / cm² were both effective in redistributing metals. The animals were exposed for 2 hours a day over a period of 10 weeks. There was an increase in copper content of the lungs, brain, myocardium,

and skeletal muscles, and a decrease in the liver and kidneys. There was an increase in iron content of the kidneys, lungs, myocardium, and liver, and a decrease in the spleen, brain, skeletal muscles, bones, skin and blood. Manganese content was elevated in the liver, spleen, skin, and kidneys, diminished in the myocardium, bones, and blood of young animals, and elevated in the blood of mature ones. Molybdenum content was lowered in the liver, brain, and myocardium, and raised in the blood of young animals. Most of these changes were substantial, for example copper more than doubled in the brain and decreased by more than half in the liver at $100 \mu\text{W} / \text{cm}^2$; iron content doubled in the myocardium of young animals at $10 \mu\text{W} / \text{cm}^2$.

Porphyria.

In this context porphyria should be mentioned, because it is a disease in which metals are not handled normally by the body, and it is evidently present in many cases of electrical sensitivity (Crumpler 1996, Firstenberg 1996, Hanson 1996, Kauppi 1996).

Porphyria manifests with a wide variety of neurological signs and symptoms reminiscent of those described for electrical sensitivity/radiation sickness. It is caused by a decrease in the activity of one or more enzymes involved in the synthesis of heme from porphyrins, and may be associated with a deficiency of heme in the affected tissues. This is consistent with the decreased activity of cytochrome oxidase, a copper-containing hemoprotein, observed in microwave exposure as noted previously.

It is possible that the 2% of the population who carry the genetic trait for certain types of porphyria are predisposed to becoming electrically sensitive if they are injured by electromagnetic radiation. Research badly needs to be done in this area.

Molecular interactions.

As noted above, heating by micro-waves is only a secondary effect of the vibration of molecules and ions by the alternating electromagnetic field. The primary influence of the waves is on the mobility of ions and the movement, orientation, polarization and configuration of large molecules (Gabovich et al. 1979).

Muth in 1927 was the first to observe the formation of chains of emulsified fat particles in 20 kHz to 2 MHz electromagnetic fields. This is now a well-known phenomenon and is called the pearl chain effect. It occurs at all microwave frequencies and was captured on film by Liebesny and Pace in 1937, using milk, blood and yeast suspensions (Krasny-Ergen 1940, Liebesny 1938). Herrick, at the Mayo Clinic, observed it in lymph (1958). Teixeira-Pinto et al. demonstrated chain formation in iron filings, starch particles, colloidal carbon particles, homogenized milk, oil suspensions in water, and colloidal polystyrene spheres, and they even constrained unicellular organisms to line up in a pulsed field of approximately $25 \text{ mW} / \text{cm}^2$. Each type of particle, they found, has particular frequencies where the effect occurs at minimum voltage (Teixeira-Pinto 1960).

I have seen numerous assertions in the recent literature to the effect that the pearl chain effect cannot occur at non-thermal intensities, but as far as I can tell these assertions are not based on any actual experiments, and fly in the face of the fact that thermal agitation will break up the pearl chains (Herrick 1958, Copson 1962). Back in the 1930s Krasny-Ergen demonstrated that the minimum field strength for pearl chain formation in the case of red blood cells is of the order of magnitude of $0.1 \text{ V} / \text{cm}$ (Krasny-Ergen 1940, p. 364). This is equivalent to a power density of only about $26 \mu\text{W} / \text{cm}^2$, eminently "non-thermal" and considerably below current safety guide-lines. And lest anyone consider this not a hazard, consider what it must do to the viscosity of the blood and the functioning of red and white blood cells to force them to all line up in chains.

In 1938 Liebesny wrote, "Although I will not assert on the strength of the above mentioned investigations that the nonthermic effects of the ultrashort wave field are fully explained, I venture to express the hope that those authors who are now of opinion that high frequency currents in general and short waves in particular can be biologically effective only by means of their heat effects, will modify their conclusion" (Liebesny 1938, p. 738). I trust that six more decades of research, as reviewed here, will at last put that absurd and meaningless argument to its final rest.

The pearl chain effect does have a definite power threshold. Other direct effects of electromagnetic energy do not, or the threshold is enormously lower if there is one. Direct effects on calcium, potassium,

sodium, and chloride ions, and on protein and lipid molecules alter the permeability of cell membranes and the functioning of enzymes. Frey (1992) provides an excellent review of both theoretical and experimental results in this area, as does French (1996). Gordon et al. (1974) mentions molecular resonance absorption, as do Gabovich et al. (1979) and Inglis (1970). Tofani et al. (1986) notes that a biological system can store energy from electric vibrations and that therefore the effects are cumulative.

Arber (1986) reports a change in potassium conductance and water permeability across muscle cell membranes when exposed to $500 \mu\text{W} / \text{cm}^2$, 2.88 GHz, and reviews similar work by other researchers. Mickey (1963) states that proteins can change their conformation and even be denatured under the influence of non-thermal intensities of pulsed radiation, provided the peak power is high and the average power low.

Akoyev (1980) provides a good review of molecular and ionic phenomena and also mentions the alteration of bound water. The importance of water as a mediator of microwave

influence may be widely underestimated, as shown by a pair of experiments done recently (Geletyuk et al. 1995 and Fesenko et al. 1995). These researchers found that potassium channel conductance in the membranes of cultured kidney cells was altered by exposure to 42.25 GHz waves at $100 \text{ W} / \text{m}^2$ for 20 minutes. They then repeated the experiment, but instead of irradiating the cells, they irradiated the buffer solution only, then put the cells in afterwards and got the same results. They found that the solution retained the memory of the irradiation for at least 10 to 20 minutes.

Thomas et al. have taken this one step further and shown that a chemical signal (TPA) can be transmitted by electromagnetic radiation alone to human neutrophils to alter oxygen metabolism. "This provides evidence that molecular signals are electromagnetic in nature, and are capable of being transmitted by purely physical means" (French 1996, p. 8).

Indeed Fraser and Frey (1968) have demonstrated that living neurons themselves emit radiation of micron wave-length when stimulated. In their experiment the unmyelinated walking leg sensory nerve of the blue crab emitted $3 \times 10^{-8} \text{ W}$ from a 0.5 mm^2 nerve surface (for a power density of $6 \mu\text{W}/\text{cm}^2$).

The capacity of electromagnetic waves to carry meaningful signals (such as telephone conversations) depends on a property we have not discussed until now: unlike ionizing radiation, nonionizing radiation has the property of coherence. Prof. Charles Susskind testified before Congress that it is this property which is likely to be responsible for many of its effects (Susskind 1968). This is understandable, because lasers, which are coherent, are much more hazardous than ordinary light, which is not. And it is also understandable if we think of disrupting the coherent signals which may be used for cell-to-cell communication by living organisms themselves.

Solid state physics.

Which brings us back to something Allan Frey said in 1971: "One problem is the assumption that we have a good understanding of nervous system function. This assumption is wrong" (Frey 1971, p. 159). As he, and Becker (1985), and Szent-Gyorgyi (1969), and Wei (1966), and Cope, and Batteau, and Augenstein all have pointed out, an accurate understanding of how the nervous system functions will have to come from the application of the principles of solid state physics and not just solution chemistry. And after that door is opened must come the realization that biological systems are at least as exquisitely tuned and sensitive to the electromagnetic world around us as any manufactured device.

For a complete review of this subject, see Frey (1971, 1988).

18. Conclusion.

The effects reviewed in this literature survey apply to all frequencies of radio waves and microwaves, but:

Centimeter waves are the most lethal to test animals (Inglis 1970)

Peak internal heating of the human head occurs at 915 MHz (Johnson and Guy 1972)

Maximum induced transmembrane potentials occur in the UHF band (Frey 1988)

Symptoms are reported most often from exposure in the centimeter wave band, and in pulsed fields (Klimkova-Deuschova 1974)

Microwave workers have a greater incidence of cardiac symptoms than radiofrequency workers (Huai 1979)

Young animals are more sensitive to microwaves than mature animals (Shutenko et al. 1981)

Children may be expected to absorb more microwave energy than adults (Baranski 1976)

In summary, the currently proliferating cellular phone (806-947 MHz), data transmission (about 900 MHz) and PCS (1.8-2.0 GHz) pulsed wave systems, according to the best evidence, are broadcasting in precisely the range of frequencies guaranteed to harm us the most, and they will have the heaviest impact on our children. Animals, wild and domesticated, will not be exempt. Flying animals, and swimming animals as we will see, will suffer the worst.

More than one scientist has noticed that the effects of microwaves are "qualitatively similar to those of ionizing radiation" (Goldsmith 1995, p. 47). Indeed, Dr. Charles Susskind of the University of California, Berkeley, in testimony before the Senate Commerce Committee in 1968, predicted, "Although ionizing radiation seems to loom larger as a hazard, it would not surprise me in the least if nonionizing radiation were ultimately to prove a bigger and more vexing problem" (Susskind 1968, p. 720).

Letavet and Gordon said in 1960, "The harmful action of UHF on the human organism, if the intensity of the emission exceeds definite levels, has been indisputably demonstrated" (p. iv). Bigu Del Blanco said it again in 1973: "The interaction of RF radiation with biological systems has been extensively studied and established beyond doubt (especially in the micro-wave region)" (p. 54). Lerner said it again in 1984: "A growing mass of evidence has virtually ended that debate. Few now question that some such weak-field effects exist" (p. 57). Marino said it again in 1988: "It is clear to all reasonable investigators that EMFs can affect physiology" (p. 993). In the late 1990s it is past time to agree that the jury is in fact in, that it has been in for some time, and that the present proliferation of wireless technology must be stopped before it does us all irreparable harm.

Let us now look briefly at some of the other impacts that the wireless revolution is having on our atmosphere, our climate, and our biosphere as a whole.

ENDANGERED SPECIES

The evidence from Skrunda proves that microwaves considerably less powerful than those from the average cellular tower do damage not just to human beings, but to plant and animal life as well. At Skrunda we have seen effects on trees that are similar to recent symptoms of dieback in forests all over the world, and we must conclude that acid rain may not be the main culprit. We have also seen proof of chromosomal damage in cows, which verifies considerable anecdotal evidence of large numbers of tumors and birth deformities in farm animals (and people) near cellular towers (Hawk 1996). Hawk also mentions the disappearance of honeybees in the vicinity of these towers, so it becomes relevant to speculate on the sudden nationwide disappearance of bees within the last year, simultaneous to the massive expansion of the cellular industry. It may not just be a case of parasites. And we have already discussed the expected impact on birds.

We have also speculated on the worldwide decline and extinction of amphibians, but this year there is a new phenomenon, and it complements the reports from farmers of farm animals born with webbed necks and legs on backwards after cellular towers go up (Hawk 1996). It seems that frogs throughout Minnesota, Wisconsin, South Dakota, Vermont, and southern Quebec are turning up with deformed legs, extra legs, missing legs, missing eyes, misplaced eyes, and other terrible deformities (Souder 1996, Hallowell 1996). The phenomenon may turn out to be much more widespread. Significantly, the species with the highest rates of deformities are those that spend the most time in the water. For example, in a seemingly pristine lake in Crow Wing County, Minnesota's most popular lake vacation district, 50% of all mink frogs were deformed this year, while American toads and wood frogs, which spend the least time in the water, had deformity rates under 5%. The connection to microwaves is speculative, but it is highly educated speculation, considering that popular vacation districts are sure to have had cellular towers erected within the last year, and considering the role water is known to play in mediating the effects of microwaves (see the discussion about mechanisms, above). Many people who suffer from electrical sensitivity also report that their illness is worse on rainy or foggy days (Hawk 1996, and personal communications).

The disappearance of fish from so many pristine mountain lakes also comes to mind. Acid rain may not be the only, or in many cases the true culprit. The electrification of the world must be seriously considered, especially as the disappearance of fish has occurred at high elevations, and the dieback of forests has been observed on ridgetops, where microwave relay towers usually go.

THE DANGER FROM SATELLITES

The proliferation of satellites we are about to witness unless this world wakes up soon is mind boggling, and no-body seems to have considered that popping thousands of them up there like so much confetti might have consequences for our atmosphere and our climate.

And there will be thousands. Orbcomm plans a fleet of 28, of which several are already in orbit. Motorola plans one fleet of 72 called Iridium, at an altitude of 485 miles, of which the first 5 were launched on May 5, 1997; another fleet of 72 called M-Star which will fly 350 miles higher; and a third fleet of 70 satellites that will fly 65 miles higher still. Odyssey's fleet of 12, Ellipso's 17, Globalstar's 56, and SkyBridge's 64 are not far behind. Neither is Teledesic, the brainchild of Bill Gates and Craig McCaw. Billed as "a kind of sky-based, wireless multi-media Internet" (USA Today, Sept. 26, 1996), this fleet of over 300 satellites is being built by the Boeing Company and already has Federal Communications Commission approval. It will orbit 435 miles above us. There are also dozens, perhaps hundreds of small companies founded by small private entrepreneurs who are already sending up fleets of smaller, cheaper satellites that we never hear about. NASA facilities in California and Florida have been converted into private space-ports. Launch facilities are being built in Alaska, New Mexico, and Virginia by companies hoping "to provide space data showing where the potholes are and whether buses are on schedule, to build systems that find hikers lost in the wilderness and oil tankers on the high seas" (Millar 1996). All of this hardware is considered disposable and will need replacements every five years, so there will be a steady stream of hundreds if not thousands of satellite launchings every year for the fore-seeable future, starting now.

The hazards are real and many.

Microwaves on the order of 10^{-7} $\mu\text{W} / \text{cm}^2$ in power will be raining down on top of us from each one of these things, and we have already seen that this is enough to be biologically active. One of the reasons for the low orbits is to place the satellites closer to the earth so the signal is stronger and the receiving antenna doesn't have to be so big, but this makes them relatively more dangerous.

Rocket exhaust destroys ozone. It has been calculated that 9 Space Shuttles and 6 Titan IV launches per year would only put enough chlorine into the stratosphere to destroy 0.1% of its ozone (Prather et al. 1990). But few people seem to be considering what hundreds or thousands of launchings will do and are doing. Aleksandr Dunayev of the Russian space agency was quoted in 1989 as saying, "About 300 launchings of the shuttle each year would be a catastrophe and the ozone would be completely destroyed" (Broad 1991). He seems to have been correct, because the calculations of Prather et al. are probably an order of magnitude too low. They themselves noted that they did not take into consideration the reactions occurring on stratospheric clouds that cause the ozone holes over the poles. And they failed to consider that the use of chlorine-containing solid rocket boosters is increasing and not decreasing throughout the world. And that other components of rocket exhaust also pose a significant threat to ozone, including water vapor and particles of aluminum oxide that seed the stratospheric clouds. Rockets and space debris burning up on re-entry also contribute such particles (Discover 1990).

We are also destroying the Van Allen belts, with consequences that are not entirely clear. For one thing, power lines and radio towers already broadcast enough energy into space to interact with the Van Allen radiation belts and cause an increase in the fallout of charged particles over the earth. This is probably enhancing cloud formation and increasing thunderstorm activity (Park and Helliwell 1978). The orbiting of huge fleets of mobile radio transmitters directly in the Van Allen belts is sure to enhance this effect. Additionally, there is already so much material orbiting the earth that the high energy particles in the radiation belts are being seriously depleted by collisions with space junk (Konradi 1988).

Rocket exhaust also produces acid rain and massive water pollution near launch sites, and contributes further to global warming by adding water vapor to the stratosphere. These effects have been judged minor, but at the planned rate of space traffic they will not remain so.

The manufacture of satellites, and also hundreds of millions of cellular phones, faxes and computers will make an already polluting industry much worse. 186 different toxic chemicals are used in the manufacture of semiconductors, for example, including acids, solvents, poisonous gases and heavy metals (NIOSH 1985). The electronics industry has become one of the largest producers of hazardous wastes and is a major polluter of groundwater all over the world.

The night sky will never be the same.

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* ABOUT THE AUTHOR

Arthur Firstenberg is president of the Cellular Phone Task force, a citizens' group formed in response to the uncontrolled growth of the cellular phone industry. He was electrically injured in 1981 after three years in medical school at the University of California, Irvine. A holistic health practitioner, he also an expert in the effects of technology upon the environment. He has been studying and writing about electromagnetic radiation for the past 15 year