electromagnetic field (EMF), electromagnetic radiation (EMR)

All known cancer-inducing agents — including radiation, certain chemicals and a few viruses — act by breaking chemical bonds, producing mutant strands of DNA. Not until the ultraviolet region of the electromagnetic spectrum is reached, beyond visible light, beyond infrared and far, far beyond microwaves, do photons have sufficient energy to break chemical bonds. Microwave photons heat tissue, but they do not come close to the energy needed to break chemical bonds, no matter how intense the radiation. --Dr. Robert L. Park of the American Physical Society (*New York Times* Oct. 1, 2002)

Ionizing radiation can break the electron bonds that hold molecules like DNA together and is carcinogenic....The photon energy of cellphone EMF is more than 10 million times weaker than the lowest energy ionizing radiation.--Lorne Trottier

Unless one is willing to discard the concept of photons, Planck's law, and the interaction between photons and atoms—and thus the entire body of quantum physics—it is simply not possible for the photons associated with either a power line or a cell phone to cause cancer."-- S. T. Lakshmikumar

An electromagnetic field (also called *electromagnetic radiation*) is a region in space through which energy passes that has been created by electrically charged particles. EMFs are produced by such things as power lines, electric appliances, radio waves, and microwaves.

Many people fear that EMFs cause cancer; however, a causal connection between EMFs and cancer has *not* been established. The National Research Council (NRC) spent more than three years reviewing more than 500 scientific studies that had been conducted over a 20-year period and found "no conclusive and consistent evidence" that electromagnetic fields harm humans. The chairman of the NRC panel, neurobiologist Dr. Charles F. Stevens, said that "Research has not shown in any convincing way that electromagnetic fields common in homes can cause health problems, and extensive laboratory tests have not shown that EMFs can damage the cell in a way that is harmful to human health."*

All electromagnetic radiation comes from photons. The energy of a photon depends on its frequency. "Roughly one million photons in a power line together have the same energy as a single photon in a microwave oven, and a thousand microwave photons have the energy equal to one photon of visible light" (Lakshmikumar 2009). Ionizing radiation is known to cause health effects; "it can break the electron bonds that hold molecules like DNA together" (Trottier 2009). "The photon energy of a cell phone EMF is more than 10 million times weaker than the lowest energy ionizing radiation" (Trottier 2009). Thus, the likelihood that our cell phones, microwave ovens, computers, and other electronic devices are carcinogenic is miniscule. Nevertheless, it is impossible to prove that no study will ever find a significant correlation between EMFs and cancer or any other disease or disorder. No product can be shown to be absolutely safe for everybody. For example, a 2004 *British Medical Journal*article claimed to have found an inexplicable increase in leukemia in children living near power lines in England and Wales. The researchers wrote: "There is no accepted biological mechanism to explain the epidemiological results; indeed, the relation may be due to chance or confounding." On the other hand, a 2003 study of women on Long Island found no causal connection between living near power lines and developing

breast cancer. A single study does not prove there is or there isn't a causal link between EMFs and cancer. We have to look at what is indicated by the preponderance of the evidence from all the studies.

There is also a strong contingent of folks hell-bent on proving this link, so it is likely that studies will continue to be done that support a contrary viewpoint. For example, a research team in Sweden found an increased risk for brain tumors in people who used cellular or cordless phones (2006). The study was a small one and assessed exposure by self-administered questionnaires. On the other hand, a large Danish study (420,000 mobile phone users) found neither long nor short-term mobile phone use to be associated with an increased risk of cancer (2006). The Danish study did not use the memories of the subjects to assess exposure; they analyzed data from mobile phone company records. Another small Swedish study found no increased risk of acoustic neuroma related to short-term mobile phone use (2004). The researchers thought that their data suggest an increased risk of acoustic neuroma associated with mobile phone use of at least 10 years duration. They don't say *how* they measured exposure, but they note that "detailed information about mobile phone use and other environmental exposures was collected." Other studies on laboratory animals have found effects from microwave exposure (2003; 2006; 2007). Some studies have collected data suggestive of possible harmful effects from cell phone microwave exposure, but they are too small to have ruled out chance or other causal agents (2006) or they have not been tested on in vivo cells (2004; 2006a; 2006b).

Recently, the alarm has been raised by some who fear that damage might be done to our brains from being exposed to Wi-Fi. Despite the fact that modulated frequencies bringing radio and television transmissions into our homes are stronger and more pervasive than the radio waves used by wireless networks, there has been little call to reduce radio or TV transmission. (The power levels for Wi-Fi are lower than that for cell phones, by the way. Photons of visible light carry more energy than microwaves and bombard us much more frequently than microwaves from such things as cell phones or wireless networks. Microwave ovens are "tuned for optimal water absorption, which happens to be about 2.45 gigahertz."* Despite numerous scare stories about the effects of microwaved water and food on people, animals, and plants, you can't do anything to food or water with a microwave oven that you couldn't also do in a conventional oven with infrared waves,* assuming you use the ovens as intended. Microwaved food is safe and poses no health hazard.)

One university president has banned Wi-Fi on his campus, claiming:

microwave radiation in the frequency range of Wi-Fi has been shown to increase permeability of the blood-brain barrier, cause behavioural changes, alter cognitive functions, activate a stress response, interfere with brain waves, cell growth, cell communication, calcium ion balance, etc., and cause single and double strand DNA breaks.*

What compelling scientific evidence he has for making such claims is not known.

Another school banned Wi-Fi after a classics teacher complained that it was making him physically ill. The teacher said that after Wi-Fi was in place:

I felt a steadily widening range of unpleasant effects whenever I was in the classroom. First came a thick headache, then pains throughout the body, sudden flushes, pressure behind the eyes, sudden skin pains and burning sensations, along with bouts of nausea. Over the weekend, away from the classroom, I felt completely normal.*

That the teacher's symptoms were caused by Wi-Fi is, however, pure speculation and unlikely. Wi-Fi goes through ordinary walls up to about 300 m, so the teacher should have felt symptoms long before entering and long after leaving the classroom. There is no compelling scientific evidence that these kinds of symptoms are

caused by exposure to Wi-Fi. There have been a number of studies that have tried to establish that some people are hypersensitive to EMFs. Ben Goldacre of Bad Science writes:

There have been 31 studies looking at whether people who report being hypersensitive to electromagnetic fields can detect their presence, or whether their symptoms are worsened by them. A typical experiment would involve a mobile phone hidden in a bag, for example, with each subject reporting their symptoms, not knowing if the phone was on or off.

Thirty-one is a good number of studies, and 24 found that electromagnetic fields have no effect on the subjects. But seven did find a measurable effect...in two of those studies with positive findings, even the original authors have been unable to replicate the results; for the next three, the results seem to be statistical artifacts; and for the final two, the positive results are mutually inconsistent (one shows improved mood with provocation, and the other shows worsened mood).*

At this time, it looks as if hypersensitivity to EMFs is a psychosomatic disorder.* (For example, a research team in Norway (2007) conducted tests using sixty-five pairs of sham and mobile phone radio frequency (RF) exposures. "The increase in pain or discomfort in RF sessions was 10.1 and in sham sessions 12.6 (P = 0.30). Changes in heart rate or blood pressure were not related to the type of exposure (P: 0.30–0.88). The study gave no evidence that RF fields from mobile phones may cause head pain or discomfort or influence physiological variables. The most likely reason for the symptoms is a nocebo effect.")

(Warning: studies on this subject are published quite frequently. No study, no matter how large and welldesigned can prove that any amount of EMF exposure is always safe for everybody under any circumstances. But the preponderance of the evidence as of spring 2008 is that there is no great danger to humans from using cell phones, Wi-Fi, or living near power lines. **update**: 9/11/2010.More results from the Interphone study have been published. The latest data can be found in the*International Journal of Epidemiology*. "CONCLUSIONS: Overall, no increase in risk of glioma [malignant brain tumor] or meningioma [benign brain tumor] was observed with use of mobile phones. There were suggestions of an increased risk of glioma at the highest exposure levels, but biases and error prevent a causal interpretation. The possible effects of long-term heavy use of mobile phones require further investigation.")

In 1997, *The New England Journal of Medicine* published the results of the largest, most detailed study of the relationship between EMFs and cancer ever done. Dr. Martha S. Linet, director of the study, said: "We found no evidence that magnetic field levels in the home increased the risk for childhood leukemia." The study took eight years and involved measuring the exposure to magnetic fields generated by nearby power lines. A group of 638 children under age 15 with acute lymphoblastic leukemia were compared to a group of 620 healthy children. "The researchers measured magnetic fields in all the houses where the children had lived for five years before the discovery of their cancer, as well as in the homes where their mothers lived while pregnant." The study was criticized because it is impossible to know exactly what the EMFs were at the times the mothers or their children were exposed. All measurements must be done after the exposure has taken place and assumptions must be made that the level of EMFs was not substantially different during exposure. It is unlikely, however, anyone except the intellectual descendants of Nazi doctor Joseph Mengele will ever do a control study on humans which systematically controls exposure to EMFs from the moment of conception through early childhood.

A report published in the Journal of the American Medical Association on a study of 891 adults who used their cell phones between 1994 and 1998 found that there was no increased risk of brain cancer associated with cell phone use (Muscat 2000).Yet, many people believe that living near power lines or using cellular phones causes cancer. Why? Some lawyers, the mass media and a scientifically illiterate public can take the credit here. Robert Pool claims popular opinion has been aroused against EMFs by unscientific sources such as *The New Yorker* magazine (Pool 1990). Paul Brodeur, called "a scientifically-ignorant writer" by physicist Bob Park, wrote three fearmongering and scientifically inept articles for *The New Yorker* in the early 1990s and published them as a book in 1993. The fear that cell phones might be causing brain tumors was aroused by ABC's "20/20" (October 1999) in a story focused on the claims of Dr. George Carlo, who, for the previous six years, ran the cell phone industry's research program on the effects of radiation from cell phones. Gordon Bass also relied heavily on Carlo for his alarmist piece in *PC Computing*, "Is Your Cell Phone Killing You?" (November 30, 1999). Carlo contradicts the conclusions of most other researchers in the field and maintains that "we now have some direct evidence of *possible harm* from cellular phones (italics added)." (Carlo also claims there is a causal connection between Wi-Fi and autism.) Contrast Carlo's view with the following:

The epidemiological evidence for an association between RF radiation and cancer is found to be weak and inconsistent, the laboratory studies generally do not suggest that cell phone RF radiation has genotoxic or epigenetic activity, and a cell phone RF radiation-cancer connection is found to be physically implausible. Overall, the existing evidence for a causal relationship between RF radiation from cell phones and cancer is found to be weak to nonexistent (Moulder et al. 1999).

In a press release on October 20, 1999, the FCC responded to "20/20" and claimed that the "values of exposure reported by ABC were well within that safety margin, and, therefore, there is no indication of any immediate threat to human health from these phones." Furthermore, the "20/20" story claimed that cell phone antennae emit radiation into the brain, which is misleading. You might also say that TVs and radios emit radiation into the brain if you put your head close enough to those devices.

Cellular phones operate at the radio frequency (RF) part of the electromagnetic spectrum. This is non-ionizing radiation. Other examples of the non-ionizing part of the electromagnetic spectrum include AM and FM radio waves, microwaves, and infrared waves from heat lamps. Unlike x-rays and gamma rays (which are examples of ionizing radiation), radio waves have too little energy to break the bonds that hold molecules (such as DNA) in cells together. Similarly, since RF of this frequency contains relatively low energy, it does not enter tissues. At very high levels of exposure, RF can cause warming of tissues, much as a heat lamp does. The wavelength of cell phone waves is about one foot and the frequency is approximately 800 to 900 MHz, although newer models may use higher frequencies up to 2,200 MHz.*

Similar arousal has been evoked by talk show hosts such as Larry King, who introduced the nation to a widower who claims that his wife's fatal brain tumor was caused by the EMF emitted from her cellular phone. There is a lawsuit, of course. The evidence? The tumor was located near where she held the phone to her ear. The major networks reported the story about the lawsuit and the brain tumor and the cellular phone. Scientists were interviewed to give the story more 'depth' and credibility. However, no scientist has yet found a causal connection between EMF and cancer, much less between cellular phones and brain tumors. So, a scientist who has exposed *existing* tumors to EMF was interviewed. He reported that his research indicates that tumors grow faster when exposed to EMF. Sales of cellular phones dropped and stock in companies that manufacture them dropped. Because tumors exposed to EMF grow more rapidly than tumors not so exposed does not indicate that EMF causes tumors, cancerous or otherwise.

It is possible that cellular phones are causing brain tumors, but the likelihood is small. The phones emit very low EMF levels and exposure to them is intermittent. It is possible that a person with a brain tumor who uses a cellular phone is running a significant risk that the tumor will grow faster than it otherwise would. As yet, however, there is no evidence to support the view that there is a reasonable probability of either.

Lawyers representing claimants who blame their cancers on power lines cite a Swedish study that found leukemia rates were 400% higher among children living near power lines. Another study, done by the University of Southern California, found increased leukemia rates in children living near power lines. According to Robert Pool,

The study examined 232 leukemia patients under the age of 10, and a group of control subjects that were matched for age, sex, and race. The amount of EMF exposure for each child was determined in a number of ways. No correlation was found between the incidence of leukemia and the electric field exposure as measured by spot checking. An insignificant correlation was noted between incidence of leukemia and levels of exposure to magnetic fields, as measured by a continual measurement over a 24-hour period. A significant correlation was seen between the EMF exposure, as measured by wire coding, and an increased risk of leukemia. Those with the highest level of exposure had a 2.5-fold greater risk of developing leukemia. It is not understood how these differences in correlation depend on the way the EMFs are measured. It is possible that some types of EMF exposure may lead to an increased risk of leukemia. On the other hand, measurements taken by wire coding may be more sensitive. Further study is needed to see what factors are being measured by the wire coding and not by the other methods. Until that is understood, it is not clear if exposure to high levels of EMFs is related to an increased risk of leukemia (Pool, 1991).

Also, Pool reports, "there have been numerous scientific reports of elevated levels of leukemia in people who are exposed to high EMF levels on the job, such as power-line repairmen and workers in aluminum smelters." Because there have been and probably will continue to be a few studies that find some sort of correlation between cancer and living by power lines,* lawyers will always be able to find some evidence, however weak, to justify filing a lawsuit. Over 201 challenges to utility projects were made in 1992 in which EMF was an issue. At least three suits have been filed in federal courts claiming exposure to utility lines caused cancer (Pool, 1991). Utility companies were scared. They poured billions of dollars into efforts to cut EMF exposure from their power lines. Dr. Robert Adair, a physicist at Yale University, calls the reaction "electrophobia" and says that it would take EMF levels 150 times higher than those measured by the Swedish researchers to pose a hazard.

Lawyers can take their cases to court long before the scientific evidence is anywhere near conclusive. And the standards of proof in a court of law are appallingly much lower than those in science. "All it's going to take is one or two good hits and the sharks will start circling," says Tom Ward, a Baltimore attorney who is suing Northeast Utilities Co. and its Connecticut Light & Power Co. unit over an alleged EMF cancer (Pool, 1991).

There is currently a great push to bury all power lines. Better safe than sorry? The cost goes up twenty-fold to bury the lines. Then what? Lawyers claiming their clients' cancers were caused by EMFed water? It was bad enough trying to sell a house with power lines nearby when people cared about the ugliness of the view. But try to sell the same house when people are afraid of getting *cancer* from the ugly lines! In any case, we will have to bury our electrical wires even deeper than our power poles are high if we are to make a significant difference in shielding us from the magnetic fields of power lines.

It is not very likely that the average person has anything to worry about from power lines cell phones, microwave ovens, cordless phones, baby monitors, or Wi-Fi. Most of us do not get that close to power lines to be significantly affected by their EMFs. Our exposure to them, even if they are nearby, is not direct, up close, and constant. The energy emitted by cell phones, cordless phones, and baby monitors (10 milliwatts) is pretty weak. There is more EMF exposure from radio and TV, and the wiring in our homes and the electrical appliances we use, than from our cell phones or Wi-Fi. No one can avoid electromagnetic radiation. It is everywhere. We are constantly exposed to it from light, commercial radio and television transmissions, police 2-way transmissions, walkie-talkies, etc. Furthermore, "while electrical fields are easily screened, magnetic fields make their way unimpeded through most substances" (Pool, 1990). In fact, it is curious that while fear of EMFs is on the rise so ismagnet therapy as a panacea and source of positive energy for the healthful-minded New Ager.

See also The Paralyzing Precautionary Principle, Cell phones, brain cancer, and other cheery thoughts, and Warning: Your Magazine May Be Hazardous to Your Health by R. T. Carroll

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reader comments

further reading

books and articles

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Wi-Fi & Autism?

news stories

new Largest Study on Cell Phones and Cancer Finds No Link The biggest study ever to examine the possible connection between cell phones and cancer found no evidence of any link, suggesting that billions of people who are rarely more than a few inches from their phones have no special health concerns. The Danish study of more than 350,000 people concluded there was no difference in cancer rates between people who had used a cell phone for about a decade and those who did not.

Paris tackles radiation from the roofs "The Mayor of Paris has halted construction of additional cellular phone towers to the city's roofs this week ... The decision to stop construction of the towers coincides with the end of the city's contract with mobile service companies. Paris is the only city in France to have an agreement with cell phone companies that limits the exposure of electromagnetic waves to two volts per meter over 24 hours. The mayor has accused the French Telecom Federation of allowing exposures of up to 15 volts per meter, levels that some reports deem unhealthy."
For more on what "volts per meter"--the standard measurement of an electrical field--means click here. "For electric fields, the WHO studies of exposures up to 20,000 volts per meter had no significant effects. Studies of animal reproduction and development with electric field exposures up to 100,000 volts per meter showed no abnormalities."*
There is much disagreement about safety among the experts, but even the most cautious safety experts say that 6 volts per meter is safe. ("Six hundred studies done over the last 20 years have shown that electrical fields, up to 6 volts per meter and magnetic fields up to 64 nanoteslars are safe, and this should cause no biological interaction, even for very long term exposure." The average bedroom has an electrical field of about 5.5 volts per meter.*) [/end]

Mobile phone use not related to increased brain cancer risk The authors [of a new study] say that because there is no plausible biological mechanism for radio waves to damage our genes directly

thereby causing cells to become cancerous, radio frequency exposure, they argue, if related to cancer is more likely to promote growth in an existing brain tumour. As such, the researchers say they would expect an increase in the number of diagnosed cases within five to 10 years of the introduction of mobile phones and for this increase to continue as mobile-phone use became more widespread. The 1998 to 2007 study period would therefore relate to the period 1990 to 2002 when mobile phone use in the UK increased from zero to 65% of households. The team, which included researchers from the Institute of Occupational Medicine in Edinburgh and Drexel University, Philadelphia, found a small increase in the incidence of cancers in the temporal lobe of 0.6 cases per 100,000 people or 31 extra cases per year in a population of 52 million. Brain cancers of the parietal lobe, cerebrum and cerebellum in men actually fell slightly between 1998 and 2007. “Our research suggests that the increased and widespread use of mobile phones, which in some studies was associated to increased brain cancer risk, has not led to a noticeable increase in the incidence of brain cancer in England between 1998 and 2007,” said Dr de Vocht.
In related news, Bob Park reports:

The Journal of the American Medical Association this week reported an NIH study of 47 healthy recruits injected with a glucose solution and then exposed for 50 min to radiation from a hand-held mobile phone. The side of the head the phone was held against was switched randomly. Positron Emission Tomography (PET) scans exhibited changes associated with glucose metabolism on the side of the brain closest to the cell phone. This was said to demonstrate that exposure to cell phone radiation activates the brain, but "the clinical significance of this finding is unknown." Hmm, that's sort of limp. I am hopeful that someone will explain to me how the effects of metabolism are distinguished from changes in blood flow associated with thermoregulation. The only effect of microwave photons is to excite molecular vibrations (heat). Blood serves as a coolant to keep the temperature of the brain nearly constant in spite of cell phone radiation.

Opponents vow to continue fight against PG&E's SmartMeters "A review of scientific studies released Tuesday by the not-for-profit California Council on Science and Technology found no evidence of health risks from SmartMeters but said more research is needed." More research is always needed.
Massive revelation in iBurst tower battle Protestors handed out flyers warning residents of Craigavon, outside of Johannesburg, SA, that microwaves from a newly erected cellphone tower would cause health problems. Soon, residents complained of rashes, headaches, nausea, tinnitus, dry burning itchy skins, gastric imbalances, and totally disrupted sleep patterns. The only problem was that even when the tower was turned off for six weeks (unbeknownst to the residents), the residents still complained of their many ailments. Thenocebo effect in action.
No Link Between Cell Phones and [Brain] Cancer in Scandinavian Study Researchers identified 59,984 cases of brain tumor diagnosed between 1974 and 2003 out of a population of 16 million from four Scandinavian countries. Cell phones were first introduced in these countries in the 1980s, but use did not become widespread until the 1990s. No difference in brain cancer rates was found after cell phone use became common.
Overuse of CT scans will lead to new cancer deaths, a study showsA normal CT scan of the chest is the equivalent of about 100 chest X-rays, but some scanners are giving the equivalent of 440 conventional X-rays.

Electrosensitive refugees from wireless technology head for Drôme

Electromagnetic fields from incubators: Italian researchers find no hard evidence of any actual health damage

Funk: Wi-Fi and autism?

Watch out for that blob of radiation! Ben Goldacre June

Wi-Fi Wants To Kill Your Children

Wi-fi health fears are 'unproven'

Mobiles 'cleared' of cancer risk

Factors that risk being left out of the equation by Ben Goldacre

A Roman Catholic cardinal and a priest in charge of Vatican Radio have been convicted of polluting the atmosphere with powerful electromagnetic waves

blogs

More EMF Hysteria (Neurologica by Stephen Novella) "The Council of Europe (COE) has recently recommended that all WiFi (wireless phones, laptops, and other electronic devices) be banned from schools, sparking another round of this controversy....The report has been widely criticized, and with good reason. While the Council cites the precautionary principle as justification, there can be a fine line between appropriate precaution and unwarranted hysteria."

Putting the EMFasis Back on the Scientific Consenus "This is about more than just wifi of course — it's a general epistemological problem we encounter in trying to derive knowledge from science. Science always leaves open the possibility that new data will be uncovered that changes an answer we'd previously relied on — it doesn't provide the certainty we humans crave." The article posts links to many sources in support of the consensus view that current evidence does not confirm the existence of any health consequences from exposure to low level electromagnetic fields.

Ontario Parents Try to Protect School Kids From Dangerous WiFi Rays After the wireless was installed, the parents of Meaford, Ontario say their children began complaining about symptoms ranging from headaches to nausea, which the children said struck while they were at school. In my day we called this illness "school-sucks-itis".

Banning Wi-Fi from Schools by Steven Novella "What we have here are the seeds of yet another grassroots movement that is disconnected from science and hostile to authority."

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