fields trigger the bone healing. Lubin now thinks he is close to an answer.

Once again, the EMFs appear to be modifying a signal that passes across the membrane—this time a signal triggered by parathyroid hormone, a substance that stimulates the breakdown of bone and inhibits bone growth. Magnetic fields, Lubin says, seem to block the action of this hormone. To test the effects of high-intensity magnetic fields on the receptor for parathyroid hormone, he did a series of experiments using monoclonal antibodies designed to recognize various parts of the receptor. Turning on a magnetic field doesn't alter the binding of monoclonal antibodies designed to mimic the hormone, Lubin says, "but the monoclonal antibodies that recognize the signal transduction region are being affected." His conclusion: "The induced electric fields are changing the pattern of charges on the surface [of the membrane] so that the receptor is not in the best configuration to transmit its signal."

Inside the cell, the result is a decrease of up to 80% in the amount of cyclic adenosine monophosphate (cAMP) , an important regulator of cell metabolism. The decrease in cAMP somehow causes an increase in bone synthesis, but that part of the picture is still out of focus.

Researchers have identified several other functions inside the cell modified by EMF exposure. Some have reported that pulsed magnetic fields can alter DNA synthesis. And in a series of experiments at Columbia University in New York City, Reba Goodman and Ann Henderson have modified RNA transcription—the process of making molecules of messenger RNA from the DNA template—and protein synthesis. Working with both 60-hertz magnetic fields and the complicated pulsed fields used to facilitate bone healing, they found that their cell cultures produced more than the normal amount of some proteins and less of others.

On the other hand, a number of experiments have shown that low-frequency EMFs apparently do not cause mutations in the cellular DNA. This is consistent with theory. Since low-frequency EMFs have too little energy to damage molecules.

So does any of the laboratory evidence point toward a connection between EMFs and cancer in humans? As with the epidemiological data, the laboratory data remains maddeningly inconclusive. The most suggestive evidence—the melatonin work—points toward breast cancer, which is not one of the types of cancer with the most epidemiological data behind it. For now, says Gyuk at DOE, what is known about the biological effects of EMFs makes it at least possible that the fields could promote cancer. But whether "possible" ever turns into "probable" depends on the results of further research. ■ ROBERT POOL

Eternal Plague: Computer Viruses

Can there ever be an all-purpose vaccine against an ever variable late 20th-century plague? No, we're not talking about AIDS here, but about computer viruses. And the answer seems to be no. Short of total isolation, there is no way to protect a computer against all possible viral attacks. That, at least, is what William Dowling finds in the September issue of the *Notices of the American Mathematical Society*.

Dowling is a computer scientist at Franklin Electronic Publishers in Mount Holly, New Jersey. His finding is an illustration of some elementary but far-reaching techniques in mathematical logic, techniques he applied to show that the existence of computer viruses is "an inevitable consequence of fundamental properties of any computing domain."

That's not to say programs designed as computer virus vaccines don't work. On the contrary, once a particular virus has been identified, it's relatively easy to combat. What is futile, Dowling's work shows, is to look for a single "magic bullet" that will eradicate all conceivable computer viruses.

Dowling considers two basic types of computer virus and shows that neither can be eradicated without severely restricting a computer's capacities. The first kind of virus simply reproduces: it is a program whose output is always a copy of itself. If a programming language is powerful enough to permit programs that interpret the language and manipulate other programs as input, then, Dowling demonstrates, those programs are inevitably open to attack by a self-reproducing virus.

The second type of virus is a program that infects and alters an operating system—the larger "environment" that programs run in but normally don't affect. In this case, Dowling finds, no single program can correctly identify all viruses unless the operating system is unalterable. Indeed, computers that store their operating system in read-only memory are impervious to this type of virus, but most computers are vulnerable, because their operating system is stored in the main, writable memory.

Dowling's second argument hinges on diagonalization, a familiar technique in mathematical logic. Diagonalization lies at the heart of Kurt Gödel's famous incompleteness theorem and Alan Turing's pioneering work on the theory of computing. Roughly speaking, diagonalization is a way of creating paradoxes out of seemingly sensible statements by making them self-referential. For example, the statement "all the statements in the *Encyclopedia Britannica* are true" is unproblematic: it may be true or false, but it is not self-contradictory.

On the other hand, the proposition "this statement is false" poses a logical puzzle: if false, it's true, and vice versa. What makes this pertinent to computer science is that computer programs, which are normally thought of as instructions for turning input into output, are themselves a kind of input. Hence they can operate on themselves and on each other in a way that is somewhat analogous to self-reference—and analogous paradoxes emerge.

For example, in the case of Dowling's second type of virus, you rapidly run into a quandary if you assume that there is a detection program that can correctly identify all such pathogens. The argument (a bit tortuous, to be sure) runs something like this. A universal virus-detection program is equivalent to one that says "yes" if a program P is safe to run with input X and "no" if running P with input X would alter the operating system. But this opens the door for a new program that can take other programs as input. The new program runs harmlessly if the detection program says "no" to program P with P itself as input, but otherwise it alters the operating system. The contradiction occurs when you ask the virus detector if this new program is safe to run with itself as input. The detector can't correctly answer "no," because then the new program would do nothing. But if the answer is "yes," then the new program would proceed to tamper with the operating system. Arriving at this contradiction implies that it is not possible to formulate such a virus-detectable program.

In practical terms, Dowling's results imply that new computer viruses will continue to appear and new vaccines will be needed. "People writing detection programs will never be out of business," he says. Alvin Thaler, program director for computational mathematics in the division of mathematical sciences at the National Science Foundation, says Dowling's demonstration gives computer virologists a sense of what they're up against. "The good news about viruses," says Thaler, "is that they're written by humans and not by nature. All you have to do [to defeat a virus] is find a smarter or more patient human, and that's easy to do." ■ BARRY CIPRA