A Unified Theory of Weak Magnetic Field Action

McGill University Professor Proposes Radical New Outlook

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Paul Héroux has a problem. He believes he has identified a way to control the growth of cancer cells, but he can't get his ideas into print. "We think we have the Rosetta Stone that will allow us to unravel the intricacies of cancer physiology," says Héroux, a professor at McGill University in Montreal. Yet, one scientific journal after another has refused to publish what he has found.

Part of Héroux's problem is that his argument is based on an even more controversial proposition than a possible cure for cancer: That extremely weak magnetic fields can bring about major changes in DNA. That *is* a tough sell. Héroux ups the ante another notch by claiming to show that those changes are so easy to spot that you don't need hi-tech instruments to see them, just a standard issue microscope. All you have to do is count chromosomes, admittedly with close attention to detail.

And that's not all. Héroux says he has pinpointed where and how the magnetic field acts on the cell.

Héroux is in McGill's Department of Epidemiology, Biostatistics and Occupational Health and runs the InVitroPlus Lab at the Royal Victoria Hospital in Montreal.

Counting Excess Chromosomes

Héroux and his former graduate student, now postdoc, Ying Li have been counting the numbers of chromosomes in cancer cells before and after they are exposed to miniscule magnetic fields, much less than a 0.1 µT or a milligauss. The science is called karyology, the study of chromosomes— the karyotype, as they are collectively called. Karyology has been around for close to a hundred years, but it long ago lost favor as a research tool to more sophisticated techniques of modern molecular biology. A change in the number of chromosomes may be a somewhat gross measure of genetic changes, but it does have the advantage of being easy to see.

Unlike normal human cells, which have 46 chromosomes, cancer cells can have a larger —and variable — number of chromosomes. (Having more than 46 chromosomes, known as hyperploidy, is usually a sign of trouble, as in Down's syndrome.)

A type of breast cancer cell, known as MCF-7, has an average of 74 chromosomes. When exposed to a 60 Hz magnetic field of as low as 25-50 nT (0.025-0.05 µT or 0.25-0.5 mG) for six days, the cells lose more than 10% of their chromosomes, according to Héroux and Li. They call the effect *karyotype contraction* and say that the change is highly statistically significant.

They repeated the same experiment with four other cell lines —those of lung and colon cancer and two different types of leukemia— and found essentially the same effect every time. The cells exposed to magnetic fields show a number of remarkable properties:

- After three weeks in the field, the number of chromosomes returns to baseline numbers;

• Once adapted to the magnetic field, the cells become exquisitely sensitive to further variations of the magnetic field. An increase or decrease of only 10 nT (0.1 mG) will prompt another round of karyotype contractions.

• The karyotype contractions vary very little over a wide range of field intensities —from 100 to 500 nT (0.1-0.5 µT, 1-5 mG). That is, there's no dose-response.

Héroux and Li concede that much of this behavior is "unusual" and runs counter to "classical toxicology and epidemiology." They say that they're in unchartered territory that's "unforeseen by conventional toxicological principles."

In all five cell lines, the effects "are strikingly similar," they write, and this suggests a "common, basic mechanism."

ATPS: A Molecular Engine That Pumps Energy into a Cell

Héroux and Li propose that the magnetic field acts on ATP synthase (ATPS), an enzyme that catalyzes the production of adenosine triphosphate or ATP, the energy source for all living cells (see figure below).

ATPS is a large molecule that spans the cell membrane and functions like a tiny engine. Protons (hydrogen ions) tunnel through the narrow channels within ATPS into the interior of the cell and, in the process, generate ATP. The efficiency of the process helps determine the energy balance inside the cell.

Here's a useful analogy from David Marcey of California Lutheran University:
Think of ATPS as a hydroelectric turbine that converts the kinetic energy of flowing water into electricity. The slower the water flows, the less electricity is generated, and vice versa. (Marcey has made an animated model which shows how ATPS works.)

According to Héroux , the magnetic fields can speed up or slow down the movement of the protons through the ATPS water channels and that this is what eventually leads to more or fewer chromosomes.

In a paper published last year in *Tumor Biology*, Li and Héroux showed that oligomycin, an antibiotic that can impair the action of ATPS, leads to karyotype contraction (as does a mix of melatonin and vitamin C). In their new paper, using this and other experimental evidence, Héroux and Li maintain that magnetic fields and oligomycin "share a common mode of action" and it takes place in ATPS.

The Russian Connection

Their new theory prompts the usual question: What biophysical force can explain how extremely weak magnetic fields can affect a biological system, in this case ATPS? Most mainstream scientists maintain that nanoTesla magnetic fields are much too small to overcome the random motion of molecules within living systems. Héroux and Li offer an answer—though it's based on some obscure and largely forgotten Russian studies.

More than 20 years ago, Lyudmila Petrovna Semikhina and her thesis advisor Professor Vsevolod Kiselev at Moscow State University found evidence that magnetic fields can alter the structure of water at levels as low as 25 nT.

It may be hard to believe, but scientific understanding of the properties of water is still a work in progress. Take, for instance, a press release issued a few weeks ago by the University of California, San Diego, describing some new twists to the molecular structure of water. It includes this statement: "Water in the active sites of enzymes affects their catalytic power." This is exactly the argument that the McGill scientists are making —with magnetic fields affecting the structure of water in the enzyme ATPS.

Here's how Héroux explained what's going on to *Microwave News*: "If the structure of the water in the proton channels within ATPS changes, the protons have a harder time tunneling through the membrane and this affects the efficiency of the rotor. This in turn leads to changes in the concentration of ATP which, in turn, triggers changes in the karyotype."

"Extraordinarily Impressive Work"

Héroux and Li summarize all this in their paper: The experimental data showing karyotype contraction in the five different cell lines, the parallels between the action of magnetic fields and biologically important chemicals on ATPS and the effects of magnetic fields on the structure of water.

It's not hard to see why journals might be reluctant to publish a paper that requires knowledge of cell biology, molecular biophysics and quantum electrodynamics. And they certainly have been. The McGill paper has been rejected by specialty radiation journals (*Bioelectromagnetics* and *Radiation Research*), more general scientific journals *(Environmental Health Perspectives* and *Carcinogenesis)* and broad interest journals (*PLoSOne*), Li said.

David Carpenter, the director of the Institute for Health and Environment at the University of Albany, took a close look at the all these results when he served as the outside reviewer for Li's doctoral dissertation at McGill. In an interview, Carpenter showered the cell line work with one superlative after another. "It is extraordinarily impressive," he said in a telephone interview. "I was blown away when I read it. It's first rate and deserves major attention."

Two long-time researchers on the effects of weak magnetic fields with backgrounds in engineering and physics are reserving judgment until they learn more about how the experiments were carried out. "The results are interesting, but I have concerns about the exposure system and the underlying theory," said Frank Barnes, a distinguished professor at the University of Colorado in Boulder, who was elected to the National Academy of Engineering in 2001. "The experimental results are much more likely to be right than the theory," he said. For more than 15 years, Barnes has been working on weak field effects with Russian scientists, notably Mikhail Zhadin of the Institute of Cell Biophysics in Pushchino.

Like Barnes, Abe Liboff, a retired professor of physics who is writing a book on *Biological Sensitivity to the Earth's Magnetic Field,* is more impressed with the biology than the rest of the paper. "Some of it is very naïve, but obviously the experiments were carried out very carefully," he said in an interview from Boca Raton, FL, where he now lives.

But possibly the best indicator that Héroux and Li are onto something important is that IREQ, the research arm of Hydro-Québec, the giant electrical utility is helping them to continue and extend this line of research. Michel Bourdages, a senior manager at IREQ, is supplying some big-ticket equipment which will allow them to do more sophisticated experiments. He is also providing funds to support Ying Li's post-doctoral work in Héroux's laboratory. Bourdages declined to be interviewed for this story.

Héroux worked at IREQ before joining McGill in 1987. While there, he designed the Positron meter, which was used in a set of influential epidemiological studies on worker exposures to EMFs. The Positron was the first meter that measured high-frequency transients that are ubiquitous in the distribution of electricity. Today, these transients are better known as dirty electricity. IREQ's backing comes with a large measure of irony; we'll come back to that a little later.

Can NanoTesla Fields Have Biological Effects?

All this raises another question: Is it even possible for nanoTesla (nT) magnetic fields to bring about biological effects? Liboff believes the answer is yes. "These very small fields are biologically active," he said, "there's no doubt about it." Liboff points to the ability of birds and bees to be guided by the Earth's static field. "Other than God's little creatures," he said, "three or four European groups have published reports of seeing effects at 40nT for time-varying fields." Liboff regrets that there is so little interest in these weak field interactions in the U.S. "It's completely different in Europe," he said.

For his part, Barnes is more conservative. He said that he's comfortable that there are effects in the tens of µT's —which is 1,000 higher than the nT fields used in the Heroux-Li experiments.

As for the Russian work by Semikhina pointing to a 25 nT threshold that lies at the heart of Heroux's grand theory, it's obscure by any measure. No one we talked to had heard of it except for Vladimir Binhi, the head of the radiobiology lab at the General Physics Institute of the Russian Academy of Sciences in Moscow and the author of *Magnetobiology*. Binhi told us that others had tried and failed to repeat her experiments. "There are strong suspicions that her results are unreliable," he said. Semikhina now teaches at Tyumen State University in western Siberia. She did not respond to a request for comment.

Although effects at nT field levels may fly in the face of current orthodoxy, they are not unheard of. For instance, last year, a group of Canadians from Laurentian University —Michael Persinger among them — reported that 1 to 5 nT magnetic fields suppressed the growth of melanoma cells in mice. The paper, though published in a mainstream journal, the *International Journal of Radiation Biology*, passed relatively unnoticed.

McGill University: A Center of Skepticism of EMF Health Effects

That Héroux, a long-time professor at McGill, is championing such a radical theory of weak-field interactions promises to lead to open conflict on campus. The university is a hotbed of EMF skepticism, promoted in large part by Lorne Trottier, a successful Canadian businessman and McGill graduate. Trottier made a fortune in the computer industry and has given vast sums to his alma mater. He is the largest donor to McGill's Faculty of Science.

Trottier has paid for new buildings, endowed professorships and last year he gave McGill C$5.5 million to bring "legitimate science to a mainstream audience." Trottier sponsors the university's Office for Science and Society, run by a close associate, Joe Schwarcz, a chemistry professor who writes popular books on science and health.

On the side, Trottier and Schwarcz run the *EMF & Health* Web site, which, they say, is "dedicated to real science." Their primary objective is dismissing any paper, report or presentation that might suggest low-level effects. They are all, without exception, attributed to pseudoscience and alarmist chatter. Trottier and Schwarcz have no doubt that cell phones, smart meters and power lines present no cancer risk or any health risk at all.

Another contributor to *EMF & Health* is Michel Plante, a medical doctor at Hydro-Québec. Plante, Trottier's point man on power line health risks, believes that the link between magnetic fields and childhood leukemia is "likely a false alarm," despite the fact that it has been repeatedly found in a large number of epidemiological studies.

Plante has a dubious history in EMF-health research. He played a central role in covering up one of the most intriguing epidemiological studies ever carried out on EMFs. That study was done at McGill under the direction of Gilles Thériault, the then chair of its Department of Occupational Health. Plante served as Hydro-Québec's liaison to the McGill team.

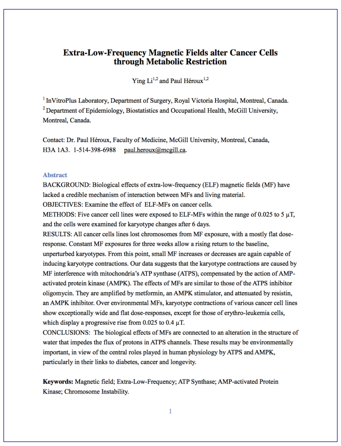
Thériault's results, which were published in 1994, showed a strong association between exposure to transients and the incidence of cancer among Hydro-Québec workers. Thériault found that the cancer risks among those most highly exposed were up to 15 times the expected rate (see *MWN*, N/D94, p.4). That study used the Positron meter to measure the workers' exposures to power line EMFs and to high-frequency transients. This is the meter which Paul Héroux helped design back in the 1980s.

Hydro-Québec was furious that Thériault had published his findings and immediately confiscated the raw data, which had been collected at a cost of millions of dollars (see *MWN*, N/D94, p.1). Further access was barred and all further research stopped. Thériault's paper is now largely forgotten. The work was never followed up.

Héroux Publishes, Bypassing Further Peer Review

Héroux is now stepping back into the EMF cauldron.

After a handful of rejection letters for his and Ying Li's paper, Héroux decided to bypass further peer review and publish the paper on the arXiv Web site, an open access archive for scientific research run by Cornell University that serves primarily the physics, math, and quantitative biology communities. (The paper was posted today, September 27.)



Extra-Low-Frequency Magnetic Fields alter Cancer Cells through Metabolic Restriction

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Abstract

BACKGROUND: Biological effects of extra-low-frequency (ELF) magnetic fields (MF) have lacked a credible mechanism of interaction between MFs and living material.
OBJECTIVES: Examine the effect of ELF-MFs on cancer cells.
METHODS: Five cancer cell lines were exposed to ELF-MFs within the range of 0.025 to 5 µT, and the cells were examined for karyotype changes after 6 days.
RESULTS: All cancer cells lines lost chromosomes from MF exposure, with a mostly flat dose-response. Constant MF exposures for three weeks allow a rising return to the baseline, unperturbed karyotypes. From this point, small MF increases or decreases are again capable of inducing karyotype contractions. Our data suggests that the karyotype contractions are caused by MF interference with mitochondria's ATP synthase (ATPS), compensated by the action of AMP-activated protein kinase (AMPK). The effects of MFs are similar to those of the ATPS inhibitor oligomycin. They are amplified by metformin, an AMPK stimulator, and attenuated by resistin, an AMPK inhibitor. Over environmental MFs, karyotype contractions of various cancer cell lines show exceptionally wide and flat dose-responses, except for those of erythro-leukemia cells, which display a progressive rise from 0.025 to 0.4 µT.
CONCLUSIONS: The biological effects of MFs are connected to an alteration in the structure of water that impedes the flux of protons in ATPS channels. These results may be environmentally important, in view of the central roles played in human physiology by ATPS and AMPK, particularly in their links to diabetes, cancer and longevity.

Keywords: Magnetic field; Extra-Low-Frequency; ATP Synthase; AMP-activated Protein Kinase; Chromosome Instability.

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Much of what is in the paper would probably have been published without too much trouble had Héroux been willing to break down his grand theory into its component parts and publish them separately. All those who have looked at the cell biology results have been impressed. In addition to those we interviewed, an anonymous peer reviewer for *PloSOne* called them "exceptionally interesting" and "very important," adding that the "effect of magnetic fields on cancer karyotype is striking" and that "the lack of a dose-response curve and the clear evidence that the effect is not secondary to induced currents is convincing." A second reviewer was equally positive. "Data presented in the manuscript show that there is a definite effect of magnetic fields on karyotype contraction," he or she wrote.

Indeed, the first reviewer suggested that Héroux and Li work would be "better served" if they would break it down into several manuscripts. Asked why he did not do this, Héroux replied that he did not want to dilute his findings by slicing them up like salami.

If Héroux's grand new theory is even partly right, he will have offered a number of testable ideas that might shed light on how to control cancer —as well as diabetes and other metabolic diseases. The cells' sensitivity to magnetic fields following repeated exposure could also lead to a breakthrough in explaining the physiological basis for electromagnetic hypersensitivity. After all, as Héroux told us, "We have no reason to believe that the ATPS of normal cells is not affected by the fields, though we think that cancer cells are more susceptible because of their enhanced metabolism."

Paul Héroux and Ying Li will now face a public peer review and, given the past history of the EMF debacle, it's likely to be quite a ride.