DISCOVER

SPECIAL REPORT

THE SHUTTLE DISASTER

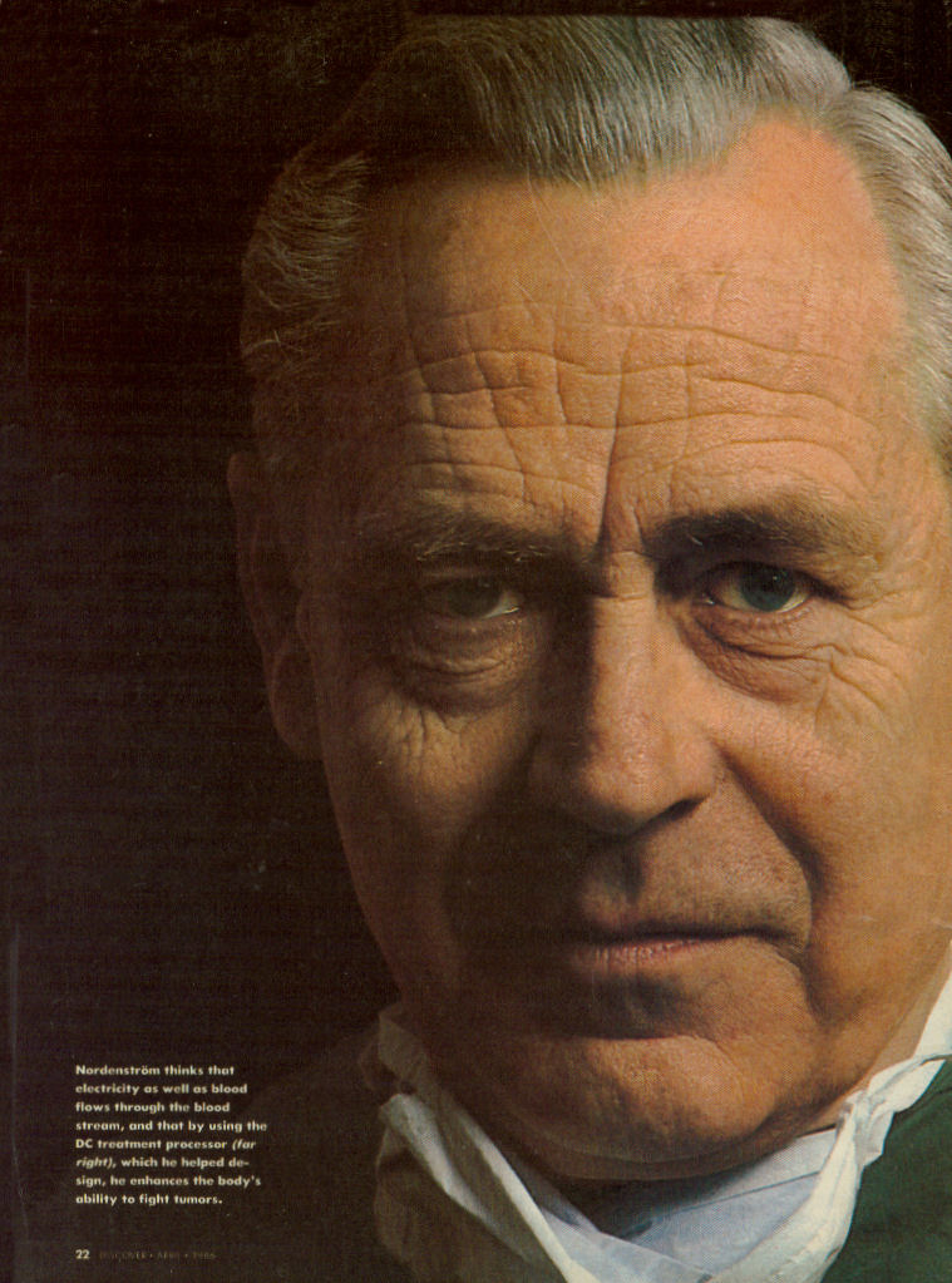
APRIL 1986

$2.50

ELECTRIC MAN

Dr. Björn Nordenström claims to have found in the human body a heretofore unknown universe of electrical activity that's the very foundation of the healing process and is as critical to well-being as the flow of blood.

If he's right, he has made the most profound biomedical discovery of the century



Nordenström thinks that electricity as well as blood flows through the blood stream, and that by using the DC treatment processor *(far right)*, which he helped design, he enhances the body's ability to fight tumors.

B Y   G A R Y   T A U B E S

AN ELECTRIFYING POSSIBILITY

Any physician who had labored to learn the academic languages and had become the disciple of some eminent professor of medicine had a heavy vested interest in the traditional lore and the accepted dogmas . . . To attack this citadel demanded a willingness to defy the canons of respectability, to uproot oneself from the university community and from the guild.

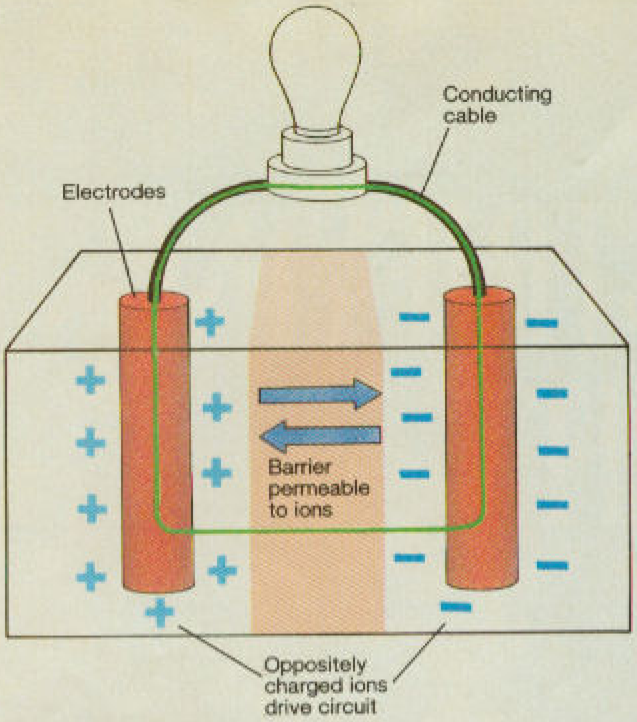
—Daniel Boorstin, in *The Discoverers*, on the state of medicine before William Harvey described the circulatory system in 1628.

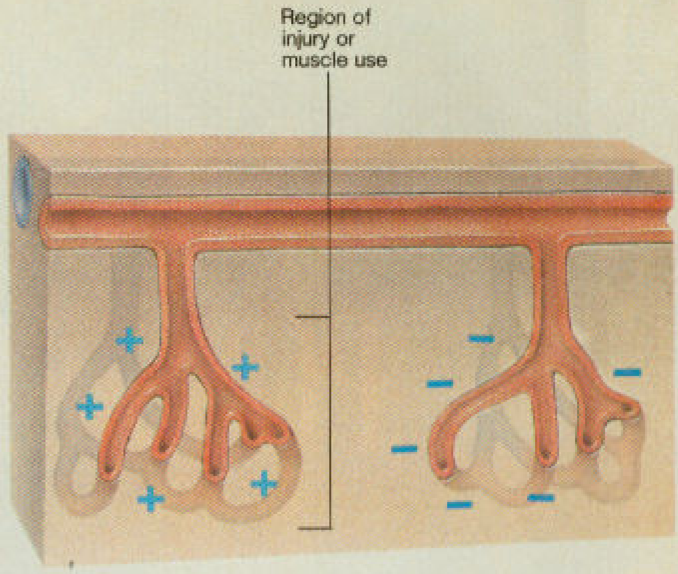
Watching Björn Nordenström operate will give you some idea of the nature of the problem. Unorthodox, to say the least.

It's a winter morning in Stockholm; still dark, although well into the day. An old man lies on the operating table, his chest quilted with scars from previous cancer operations. He has a new tumor in what the surgeons have left him of his lungs. Nordenström has been given permission to treat him, because the old man doesn't have

A Swedish radiologist posits an astounding theory: the human body has the equivalent of electric circuits

PHOTOGRAPHS BY GEORG FISCHER, ILLUSTRATIONS BY LEWIS E. CALVER





NORDENSTRÖM'S CIRCUITS: A BIOLOGICAL BATTERY

1 According to Nordenström's theory, the mechanism of the body electric can be compared to that of a battery. In a battery, the circuit is driven by the separation of oppositely charged ions. Once the circuit is closed, long-distance current flows through the conducting cables; within the battery, ions drift across the permeable barrier.

BUILDING ELECTRIC POTENTIAL IN THE BODY

2 Injury or even normal muscle use will result in a build-up of positively charged ions in the affected tissue. In relationship, nearby tissue appears negatively charged. This separation of charge sets the stage for the long-distance flow of electricity.

enough lungs left to remove, and if something isn't done he'll be dead in a year. Still, the old man, prepped with Valium, is conscious and smiling.

Nordenström is tall and greying, with a military bearing; the deep lines under his eyes are signs of both his 65 years and his propensity to overwork. Beneath his surgical gown he wears a rubberized radiation vest. He takes hold of a foot-long needle and stares down at the old man's chest. Guided by x-ray equipment of his own design—which gives views of the patient's chest from front to back and side to side—Nordenström inserts the needle, with a slight jerk to get it through the chest muscle, directly into the center of the tumor. He takes up another needle and slips it in ten inches below the first. The needles are platinum electrodes. He hooks wires to each, then turns to his assistant and nods. The assistant twists a dial on an orange box, and the treatment begins.

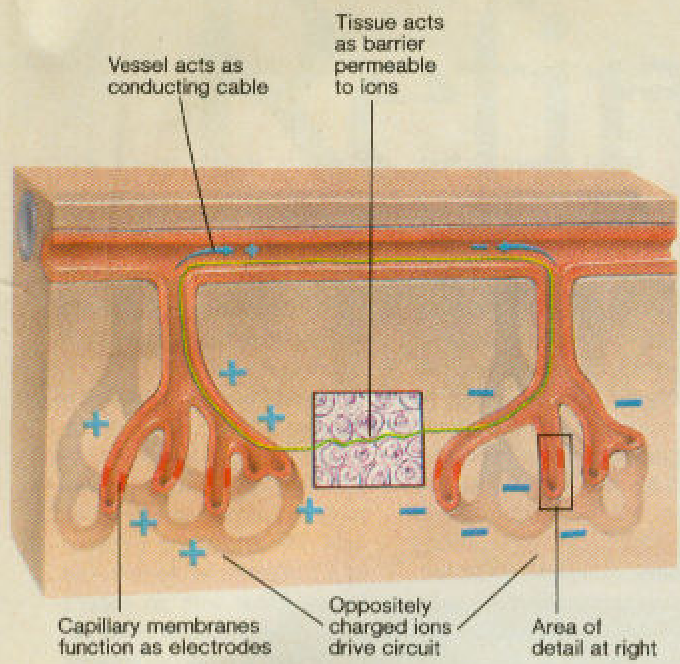
Nordenström asks his patient if he feels any pain, and the old man says no.

A few minutes later, Nordenström doffs his gown and radiation vest and settles down on a chair next to the operating table. One of the nurses brings him and the old man coffee and cookies. All the while, electric current courses through the old man's chest.

So there Björn Nordenström sits, calmly sipping his coffee while he tries to save the life of another man with a technique that looks as if it has been cooked up by a maniacal electrician with delusions of grandeur. But Nordenström is no quack. Not by a long shot: his track record, as a physician and researcher, is as good as anyone's. In the 1950s he pioneered a series of remarkable innovations in clinical radiology that seemed radical at the time but are now routinely employed at every major hospital in the world. In the 1960s he was promoted to the most respected position in his field: head of diagnostic radiology at Stockholm's Karolinska Institute, then the pre-eminent radiological research laboratory in the world. In 1985 he served as chairman of Karolinska's Nobel Assembly, which chooses the laureates in medicine. He is, in the words of Morris Simon, the director of clinical radiology at Boston's Beth Israel Hospital, "a brilliant, very innovative, very imaginative scientist, who has made significant contributions to radiology and medicine."

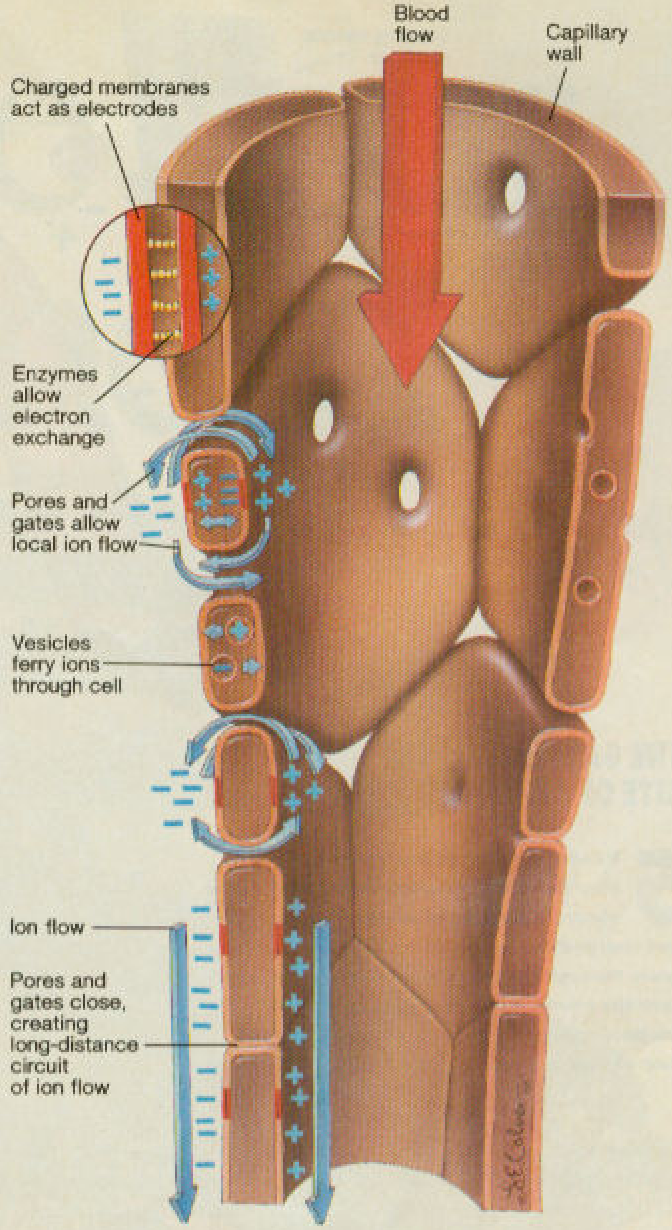
In 1983 Nordenström published a 358-page book covering more than two decades of experimental work. It's entitled *Biologically Closed Electric Circuits: Clinical, Experimental, and Theoretical Evidence for an Additional Circulatory System*, and it's potentially revolutionary. Nordenström claims to have discovered a heretofore unknown universe of electrical activity in the human body—the biological equivalent of electric circuits.

As Nordenström describes his body electric, the circuits are switched on by an injury, an infection, or a tumor, or even by the normal activity of the body's organs; voltages build and fluctuate; electric currents course through arteries and veins and across ca-



HOW CURRENT FLOWS THROUGH THE BLOOD STREAM

3 The biological circuits are driven by the accumulated charges, which, unlike those in a battery, oscillate between positive and negative. The larger vessels act as insulated cables, blood plasma as the conductor. In the permeable tissue, the fluid between cells conducts ions. A key component of the circuit: the natural electrodes in the capillary walls.



CAPILLARIES CLOSE THE CIRCUIT

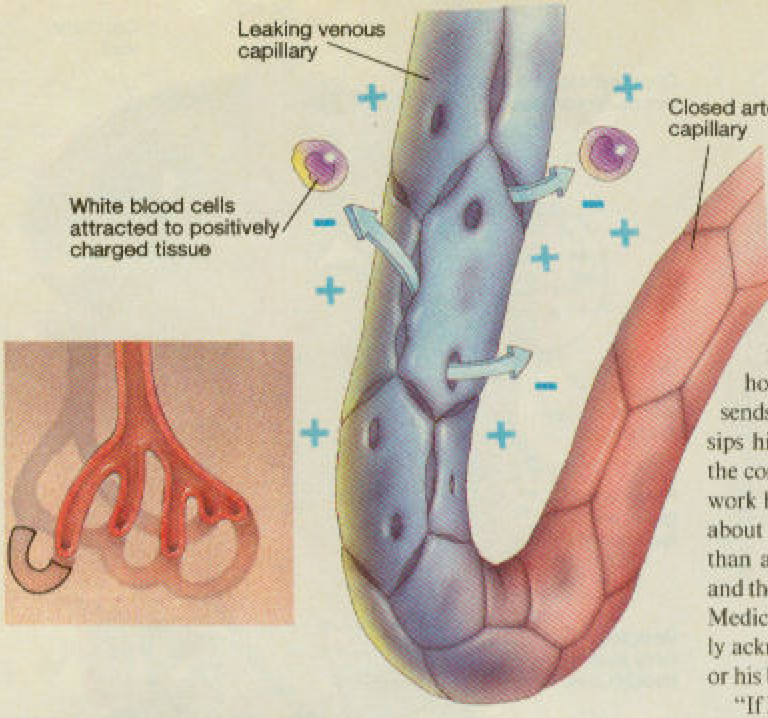
4 The membranes of the cells of the capillary walls are known to be charged, causing ions to circulate through the cells, via gates and vesicles, and between the cells, via pores. Electrons cross an enzyme bridge *(yellow)* through the capillary wall to close this local circuit. Nordenström discovered that arterial capillaries contract when subjected to an electric field like that caused by the accumulation of charge at a site of muscle use or injury. As a result, the pores and gates close, blocking the local ionic current so that the ions flow through the blood stream and along the capillary walls instead. Thus the long-distance circuit is switched on.

pillary walls, drawing white blood cells and metabolic compounds into and out of surrounding tissues. This electrical system, says Nordenström, works to balance the activity of internal organs and, in the case of injuries, represents the very foundation of the healing process. In his view, it's as critical to the well-being of the human body as the flow of blood. Disturbances in this electrical network, he suggests, may be involved in the development of cancer and other diseases.

The idea that electric currents can stimulate bodily repair, alert defense mechanisms, and control the growth and function of cells is not a new one in medicine. Bioelectromagnetics dates back at least 200 years. But the field picked up a dubious reputation at the turn of the century, when researchers who had proposed electromagnetism as a panacea were proved wrong, and the stigma has lingered ever since.

Enter Nordenström. His book is neither an esoteric piece of theorizing nor the result of a single isolated experiment. He backs up his statements, theories, and conclusions with a wealth of meticulous and ingenious experiments, with one clinical observation after another, with theoretical proofs, and with known facts. He makes a strong case, and, at least as far as he's concerned, he has proved it.

Nordenström doesn't spare his medical colleagues from the jab of his needles. To him their attitude toward electricity in the human body is almost medieval. Knowing of the "enormous importance of



THE GATEWAY TO THE SITE OF AN INJURY

5 Venous capillaries don't contract in an electric field. Attracted or repelled by the electric potential of an injury, ions and charged cells, e.g., white blood cells, migrate through the pores of a venous capillary near the injury. Because the injury's electric potential oscillates, it creates an ebb and flow of charged cells and ions, critical to healing.

closed electric circuits in modern electronic technology," asks Nordenström in the conclusion of his book, "is it seriously plausible that biology can 'afford to ignore' the exceedingly efficient principle of transporting electric energy over closed circuits?"

Classical medicine certainly doesn't deny that there are myriad electrical forces at work within the body, in addition to chemical ones exerted by hormones and enzymes, and physical ones like the pressure of the blood in the arteries and veins. Every human thought and action is accompanied by the conduction of electrical signals along the fibers of the nervous system. Indeed, life wouldn't exist at all without a constant flow of ions across the membranes of cells. Yet Nordenström argues that this picture is incomplete. As he sees it, medical research has provided a descriptive view of the chemical and physical processes at work in the human body, but hasn't explained how they're interrelated. It's a picture of effects without causes. In Nordenström's view, the cause behind many of the effects is the ebb and flow in his biologically closed electric circuits.

If Nordenström is right, these circuits may explain many fundamental regulatory processes in the human body, and even the seemingly inexplicable therapeutic effects of acupuncture and of electromagnetic fields.

To prove that his theory is more than just an academic curiosity, Nordenström has put his ideas to work, using electricity to treat lung and breast tumors. Considering the immaturity of his science, he has had remarkable success.

In the two hours before Nordenström unhooks the electrodes and sends the old man home, he sips his coffee and talks about the complete lack of impact his work has had. He's talking less about his cancer treatments than about his basic research, and there he's a little perplexed. Medical researchers have barely acknowledged Nordenström or his book.

"If I'm right," Nordenström is saying, "time works for me."

His voice is raspy; though heavily accented, his English is good. He tells of years of careful experimenting—hypothesis and test. Classic scientific method.

"When I had the whole material ready" he says, "nobody wanted to publish it. 'To whom should we direct the message?' they asked. I said to everybody—to biologists, to all doctors. They should know about this. Then they said, 'We don't dare to publish it.' If I had done only one experiment, they would probably very easily accept it. But to prove my theory I had to do so many things based on the same principle and they [the medical community] say it's crazy because I say it explains everything. I understand, but this is the difficult thing for me. It's so basic and so important because it plays so many roles in every biological reaction. *It's not my fault.*"

Nordenström laughs.

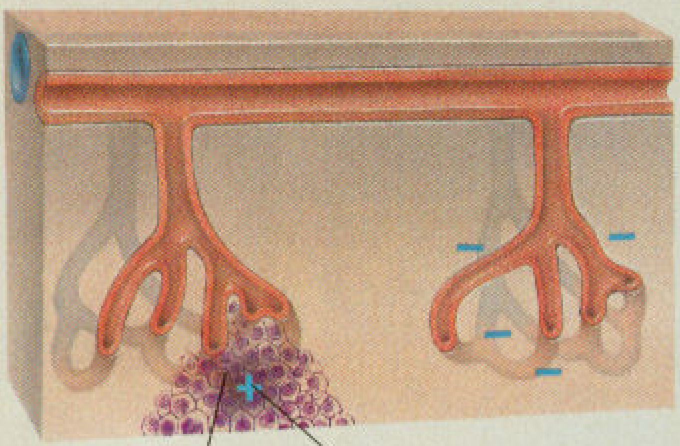
In 1984, a full year after his book came out, the first review appeared in the medical press, in the journal *Investigative Radiology*. The journal doesn't usually print book reviews, the editor wrote, but Nordenström's work presented such "fundamental and far-reaching concepts that a review was deemed desirable . . . The importance of the concepts presented in Dr. Nordenström's book cannot be overemphasized." The reviewer went on to call the book "remarkable" and "a seminal work."

A year later, a second article appeared, this one in the *American Journal of Roentgenology*. The *AJR* is one of the two most important journals in the field. The article was a rewrite of a Nordenström lecture, and it, too, came with an editor's note: the publication of the paper, it said, was unconventional and required an explanation. The work was unique, the editor wrote: unlike the multi-author publications common in journals, it was all the work of one man—Nordenström. "He alone is responsible for the original concepts, the experiments, the analysis and the text. Although employing modern terms and instruments, his performance has been in the tradition of the pioneer scientist: complete and isolated immersion in the research." The journal said that a final judgment was premature, but that, at the very least, the work was "imaginative, experimentally ingenious, and provocative" and deserved serious examination by the medical community.

No such examination has yet been made, although four small groups of researchers—one each in France and Italy, two in Japan—are beginning to replicate Nordenström's experiments. "His work is far too original," says John Austin, a Columbia University radiologist, who helped edit the book. "It's far too wide ranging. Nobody in this country is beginning to touch what he's doing."

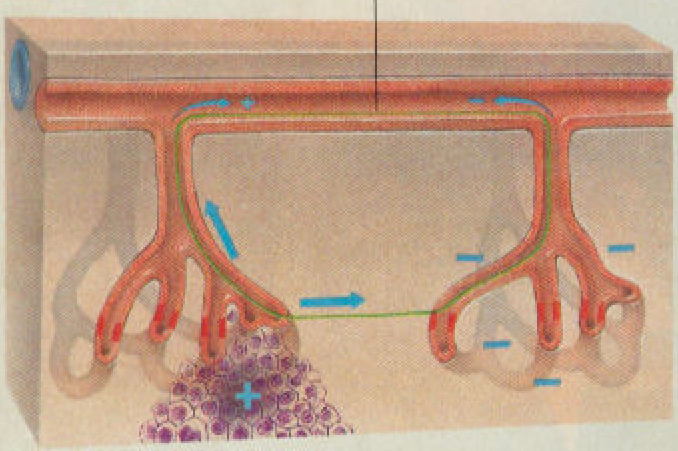
Some of Nordenström's American colleagues—highly respected men in the world of medicine—say his work is undeniably revolutionary. If it's

CANCER IS AN INJURY THAT CREATES A CIRCUIT



BUILDING A POSITIVE CHARGE

As a tumor grows, the inner cells are cut off from the circulatory system and slowly die. This cell death leads to chemical changes and, initially, the build-up of a positive electrical potential in the tumor.



ACTIVATING THE CIRCUIT

The tumor's positive charge polarizes nearby tissue, turning on the long-distance circuit. Ions flow through blood vessels linked to the tumor, as well as percolating through the tissue around the tumor.

right, it's important not only to medicine but to all of biology. (They'll compare it to Harvey's 1628 treatise on the circulatory system, but they don't want to have such claims attributed to them.) And if it's wrong, they say, the experiments themselves are brilliant in any case. What Nordenström desperately needs, says Beth Israel's Simon, "is to have people persuaded that it's worth making a major effort to prove or disprove what he says."

The mystery is why the medical community has barely noticed that Nordenström's theory exists. If you were to ask radiologists at random about Björn Nordenström, you'd be lucky to find one who knew his name. If you asked cancer experts, or biophysicists, or pathologists—scientists whose disciplines are the heart and soul of Nordenström's book—you'd probably get a blank stare. Björn who?

Nordenström was born in 1920 in Ragunda, a village in central Sweden, and was raised in the city of Bollnäs, where his ancestors have lived for three hundred years. He studied at the University of Uppsala, and finished his medical training in Stockholm. After World War II, he joined the Swedish Red Cross and spent three months touring southern Austria with another doctor, immunizing orphans against TB. He estimates they had inoculated 25,000 children by the time his wife called to tell him she was pregnant (with the first of their three boys).

Back in Stockholm, in 1949, he began a career in radiology. He picked his speciality the way many people do—someone offered him a job that paid well, and it turned out to be interesting. He also apprenticed for a year with the Swedish surgeon Clarence Crafoord, one of the pioneers of open heart surgery, before going to the University of Michigan on a one-year fellowship. At Michigan he was an innovator in the use of both radio-opaque chemical dyes and a method known as balloon catheterization, for producing more distinct x-ray images of the heart, blood vessels, and lungs.

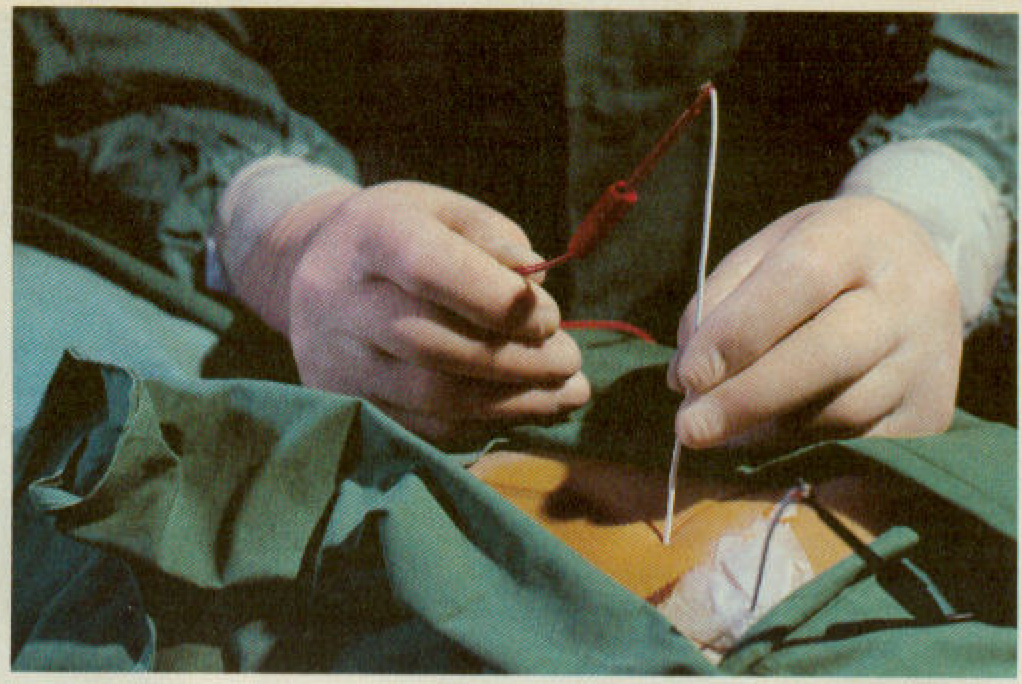
In the autumn of 1956 Nordenström returned to Stockholm and began searching for a way to determine, without cutting open the chest and lungs, whether a lung tumor was malignant or benign. He had an ingeniously simple solution: under x-ray guidance, stick a needle through the chest wall and into the tumor and remove a tissue sample, then examine it under a microscope—"a practical, valid approach to the thing," he calls it.

Nordenström had pioneered what's now known as percutaneous needle biopsy, a diagnostic technique used in every major hospital in the world. But before he could put it to use, he had to redesign the biopsy needles employed to penetrate deep into the body, and the x-ray equipment needed to steer them to the tumor. His colleagues showed the usual hesitation: much too dangerous a procedure, they said; Nordenström was much too aggressive. And it was nearly two decades, not until the 1970s, before Nordenström's biopsy technique finally caught on in America. Says Richard Greenspan, head of radiology at Yale Medical School, "Before Nordenström came along, if somebody had told me you could take a needle and shove it into a lung and biopsy a tumor, I'd have been shocked."

Nordenström refers to these innovations as the first waves of his career. The latest wave is his theory of biologically closed electric circuits, which also began building in the 1950s, when his curiosity was piqued by a subtle phenomenon he observed in his practice. Every so often he would see in his x-rays the forbidding mass of a tumor nestled within the lung, and around it a halo of light-colored streaks radiating from its edges. Because the image reminded him of the rays of the sun, he called it a corona. He looked at thousands of tumors, but only some were surrounded by coronas, while others—of the same size, shape, and location—had none. More puzzling, a corona might show up in one x-ray and then fail to appear in a later one. When Nordenström showed his x-rays to other radiologists, they seldom spotted the coronas. When they did, they considered them trivial and wondered why Nordenström cared.

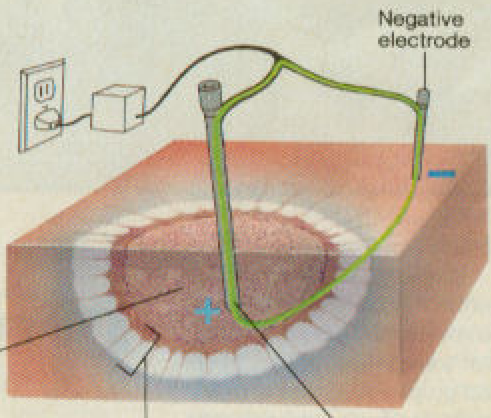
For nearly ten years he tracked the coronas on his x-rays, but found nothing that could explain their origin or significance. Even when he used his biopsy needles to sample tissue from tumors with and without coronas, he discovered no consistent differences between them.

Finally, in 1965, he decided to perform what he calls a systematic exploration, and began to test the electrical properties of the tumors. This was as much by necessity as by choice. First, he had little else left to try: a tumor in the body is inaccessible to the resources of a laboratory, but take the tumor out of the body and you may destroy the conditions that created the corona. Second, because he was working with human cancer patients, it was one of the few experiments he could perform without increasing the risk to the patient beyond that already entailed in doing a biopsy. Nordenström says, "I thought to myself, 'Isn't this silly, just to introduce a needle to take out samples of materials? Perhaps I could see something more, study something more when I'm in



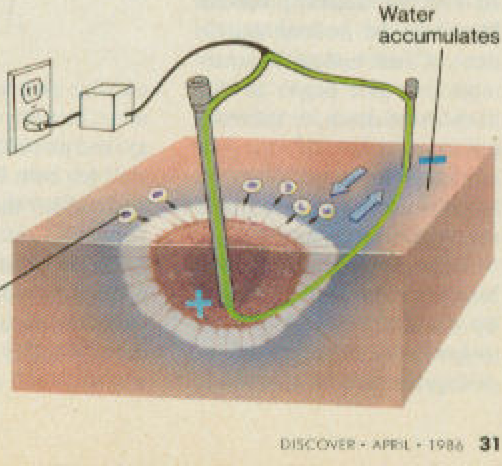
INSERTING THE ELECTRODES

A corona arises naturally during the tumor's electropositive phase: spikes appear on he surface of the tumor, and water *(blue)* moves into the surrounding tissue, dehydrating the tumor and forming a series of radiating structures and arches. Nordenström inserts a positive electrode into a breast tumor and a negative one into normal tissue near by.

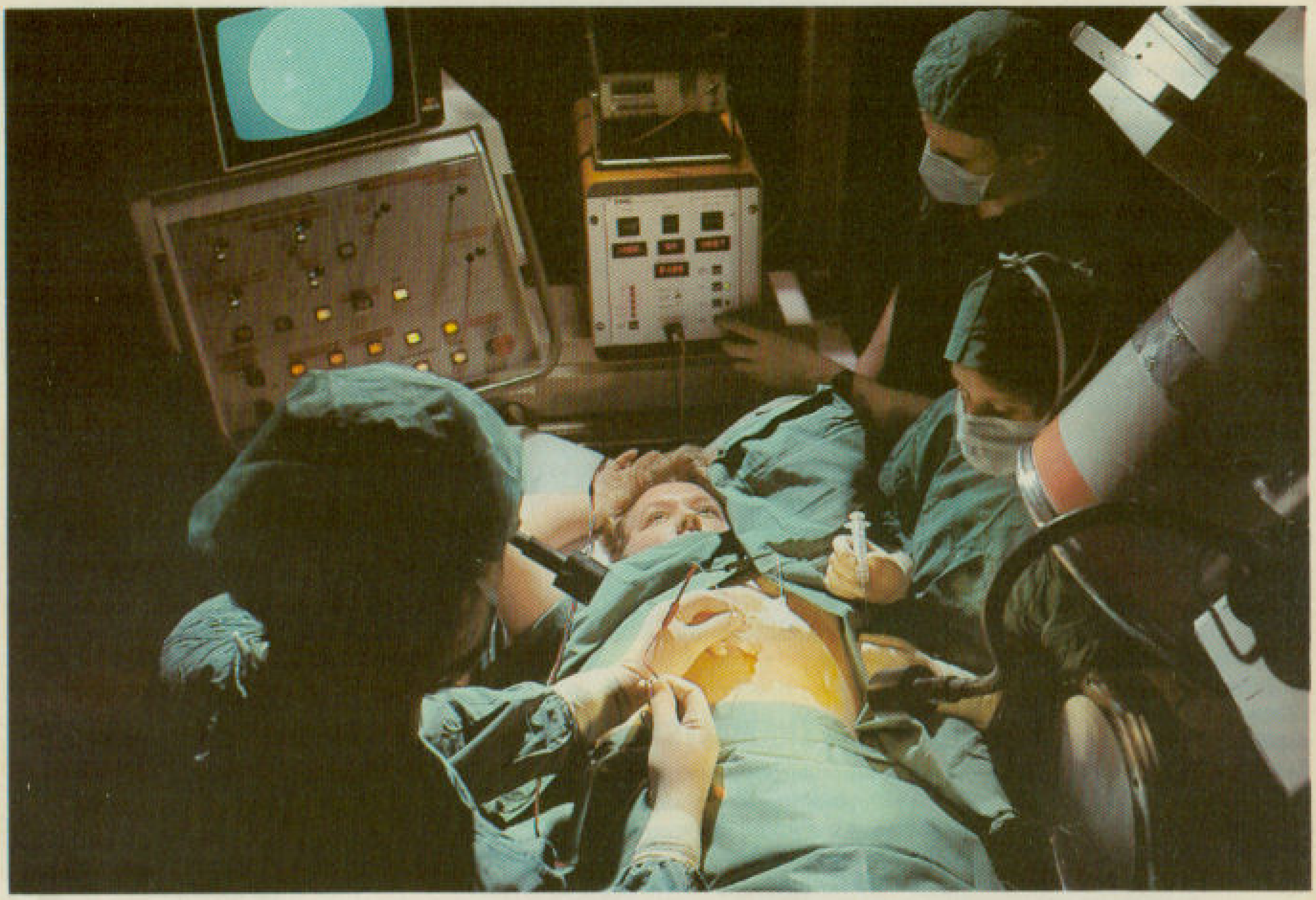


ATTACKING THE TUMOR

By running current into the tumor, Nordenström amplifies and prolongs the electropositive phase of the already existing circuit. According to him, the current will trigger a variety of tumor-fighting effects, among them producing acid in the center of the tumor and attracting white blood cells. Water accumulates at the negative electrode.



At Karolinska, Nordenström *(left, below)* applies his unorthodox treatment to a breast cancer patient.



there with my instruments.' "

So Nordenström turned his needles into electrodes and combined the sampling of tissue with the study of the electrical properties of tumors in the body. He measured the electric potential of the tumor compared to that of surrounding tissue—the voltage, in essence—and found that tumors with coronas were frequently associated with an electric potential. Moreover, he noticed that in many of these tumors the innermost cells had begun to die. Such tissue death, or necrosis, occurs when the cells at the core of a tumor are cut off from the blood stream as the outer cells continue to proliferate.

These experiments absorbed Nordenström almost totally. By the late 1960s he was no longer doing conventional radiology; instead he was slowly moving, experiment by experiment, into physiology, oncology, and pathology. He had created his own field of science, and had left the establishment behind.

He refused to take on an assistant; he wanted to do every experiment himself

To understand the electric potentials in the tumors, Nordenström measured the potential of blood as it slowly deteriorated. Blood was the only tissue he could extract from the body without worrying about damaging it in the process. He found that the electric charge in the decaying blood was first positive, then negative; over the course of days it oscillated slowly between the two states until all the blood cells had died off. These results could explain the variations in voltage he had discovered in the tumors, and became the basis for one of the key points in his theory: any injury to the body creates a voltage that continuously fluctuates between positive and negative until it finally reaches electrical equilibrium—a state Nordenström believes is associated with healing. Nordenström later found that the release of energy by injured and dying cells could be the driving force—the battery—of his electric circuits.

Next, Nordenström carefully measured the electrical properties of veins, arteries, capillaries, and blood in living animals. He found that the electrical resistance of the walls of the veins and arteries was at least 200 times that of blood. In effect, he claimed, these vessels were acting as insulated cables, and the blood flowing within them conducted electricity between the tumor and the surrounding tissue. That much was high school physics.

Then he designed experiments to test his theory. He hooked his electrodes to the blood vessels of dogs and showed that the current flowed preferentially through the veins and arteries. When he applied an electric current to the blood vessels, white blood cells, which carry negative charges on their surface, were attracted to the positive electrode. Blood clots, too, would form in the vessels in response to the current. The attraction of white blood cells to injuries isn't well understood by scientists, yet Nordenström seems to have demonstated that a simple, fundamental principle underlies it.

Nordenström spent most of his waking moments on his research. He made mistakes; he repeated experiments again and again. He worked absurd hours for the laid-back Swedish life style. He got to bed by ten but woke up to do his creative thinking between three and five in the morning; he would lie in the dark, reviewing his problems from the previous day and planning his experiments for the next. He refused to take on a junior researcher, because he wanted to do every experiment himself, so that he would have first-hand information and would know how best to proceed.

By 1978 Nordenström had completed his basic research: he had identified all the elements of an electric circuit in the body. In the vascular interstitial closed circuit, or VICC, as he called it, necrosis in a tumor functioned somewhat like an AC power source. It built a fluctuating potential, driving the circuit with a slowly alternating current. The blood vessels served as electric cables between injured and healthy tissue. The blood served as one segment of the conductor in the circuit; the fluid between the cells of tissue—called interstitial fluid, it's as conductive as the blood—served as the other. Enzymes in the cells of the capillary walls formed the system's electrodes. Says Nordenström, "When you have found all the elements that correspond to an ordinary electric circuit, and each element performs its defined function, it must work."

By then the medical establishment and Nordenström had lost touch. He had given few lectures on his research and had published only a handful of papers. When he began writing his book in 1979, he was convinced he had proved his thesis of biologically closed electric circuits. But even the handful of colleagues who knew of it didn't seem to care. When he finished the book in 1983, medical publishing houses refused to take it seriously, so he raised $50,000 and published it himself. Of the 2,000 copies printed, only 400 were sold. What he considered the most important work of his life languished in obscurity.

Nordenström was as much to blame as anyone. He had committed one of the cardinal sins in research: he rarely bothered to publish in the medical journals, the traditional network of information in this branch of science. Instead he chose to pack two decades of effort into a single tome. (Although Nordenström has published 140 papers in his life, only a few are on his biological circuit research.)

Researchers hesitated to buy a book about a seemingly bizarre new field—even more so because Nordenström was asking $135 per copy to cover his publishing costs. Moreover, the book hadn't been subjected to peer review, as articles in a top journal would have been. Says Melvin Figley, a professor of radiology and medicine at the University of Washington, and recently editor of the *AJR*, "It's conceivable that it's all very solid, but it's not presented in the conventional way."

Nordenström responds that he did publish three papers, one in 1971, one in 1974, and one in 1978. "But there was no response whatsoever," he says. "I published and I talked about it with my colleagues, and they didn't understand. They just said it was a crazy idea, nothing of importance."

After that, he insists, he was more interested in pursuing his research than in publishing it, which isn't quite as rebellious as it sounds. Most researchers write up their experiments to earn promotions in academia's highly competitive publish-or-perish climate. Nordenström needed no promotions; he was already at the pinnacle of his field.

Nordenström might not even have written the book if it hadn't been for a minor stroke in 1979 that knocked him out of action for half a year. "I was so scared when I was ill," he says, "and I was so afraid that maybe I would get a heart attack. I had to write it down so it wouldn't be forgotten." Although both his parents are

Nordenström resigned as a Karolinska administrator to devote himself to his research

alive and in their nineties, Nordenström insists that his life has been more stressful than theirs. He began the book while he was recovering, and now that it's out, he doesn't want to repeat what he's already written. "At the moment," he says, "the primary scientific work is the most important to me. Later on I can publish. When I have exhausted myself in the scientific field, and for various reasons cannot do my job, then I can write up things in articles."

Figley, an old friend and colleague, says he had to ask Nordenström to submit the article on his work to the *AJR*. The two belong to the Fleischner Society, an international group of prominent radiologists and other medical specialists interested in lung diseases. The article came from a lecture that Nordenström gave to the society. (Nordenström says that after the talk those present raved about his work, but only five of the 62 members bought the book.) It was Figley who added the *AJR* editor's note, which although overwhelmingly complimentary of Nordenström, struck some researchers as a not-so-subtle disclaimer that said, in effect, that because the experiments hadn't been replicated or reviewed by other scientists, the article shouldn't be construed as representing the journal's usual standards for new research.

There's obviously confusion over Nordenström's work even among those colleagues who know something about it. They acknowledge that his experimental observations may be right—no one has yet come forth to point out a mistake—but suggest that his overall synthesis may be a little far-fetched. Nordenström himself is convinced of the validity of his basic thesis, even if he may have erred in a few particulars. But when he goes on to assert that electric circuits in the body can explain so many puzzles, from subtle x-ray findings in lung cancer, to accumulation of white blood cells, to acupuncture, it only increases suspicions of quackery among the more traditionally minded.

That uneasiness was compounded by Nordenström's resignation from his administrative duties at Karolinska Hospital in 1979. He wanted to devote himself to his research, he says, and leave behind the burden of paperwork—of presiding over a department of 250 people, including 48 full-time doctors. The hospital administrators, who prefer their department chiefs to concentrate on patients and management, not on research, were happy enough to let him go.

Outside observers hearing rumors of Nordenström's resignation could only wonder if it had been subtly encouraged by the Karolinska administrators because they felt he had lost touch with reality. As one U.S. researcher put it, "The question in everybody's mind is whether he has become such a recluse that it has interfered with his ability to do science."

Nordenström, who seems quiet and stoic by nature, adds to the doubts by coming off as a bit of a zealot on the subject of his work. He admits that he sometimes feels like a nineteenth-century missionary working in darkest Africa. Figley says that when he went over Nordenström's manuscript before publication in the *AJR*, Nordenström was unreceptive to any other views of his work, even serious criticisms. He seemed satisfied with his own verifications, and that was that. Says Figley, "Nobody doubts his sincerity and integrity, but he has an almost religious fervor about this that I think obscures his objectivity."

Perhaps the key obstacle to the acceptance of Nordenström's theory is its challenging interdisciplinary nature. Although it takes off from Nordenström's own discipline of radiology, it quickly veers into biophysics, biochemistry, pathology, and tumor physiology, to say nothing of elementary physics. Radiologists, by and large, can't understand it. In their field, learning means keeping up with the explosion of new technology—CT and PET scans, magnetic resonance imaging—not returning to the biochemistry and biophysics they studied way back in medical school. Yet it's just such basic scientific knowledge that Nordenström's book demands. Says John Doppmann, head of diagnostic radiology at the U.S. National Institutes of Health (NIH), "I doubt whether a dozen radiologists have read it, because they wouldn't be able to evaluate it anyway."

The few experts in bioelectromagnetics who've heard of

He admits that he sometimes feels like a missionary working in darkest Africa

Nordenström and might be able to evaluate his work submit conflicting testimony. For instance, when W. Ross Adey of the V.A. Hospital in Loma Linda, Calif. reviewed the current state of his field in *The Sciences*, he never mentioned Nordenström's research. He later explained that although he owned Nordenström's book, he hadn't yet read it. Andrew Bassett, a professor emeritus of surgery at Columbia who has used electricity to help heal bone fractures, criticizes Nordenström as a newcomer who has placed too much importance on his own results, and ignored the body of existing knowledge. Some, like Boguslaw Lipinski, an associate editor of the *Journal of Bioelectricity*, say Nordenström's findings are fascinating and original, and seem to fit perfectly into what's already known about bioelectromagnetism. Lipinski goes even further, saying Nordenström's research is the first to make the scattered theories and experimental results acceptable and understandable in the total context of the human body. If Nordenström can bring the field recognition, he adds, "that is the most important thing that he can do." In other words, bioelectromagnetists may be able to ride to respectability on Nordenström's coattails.

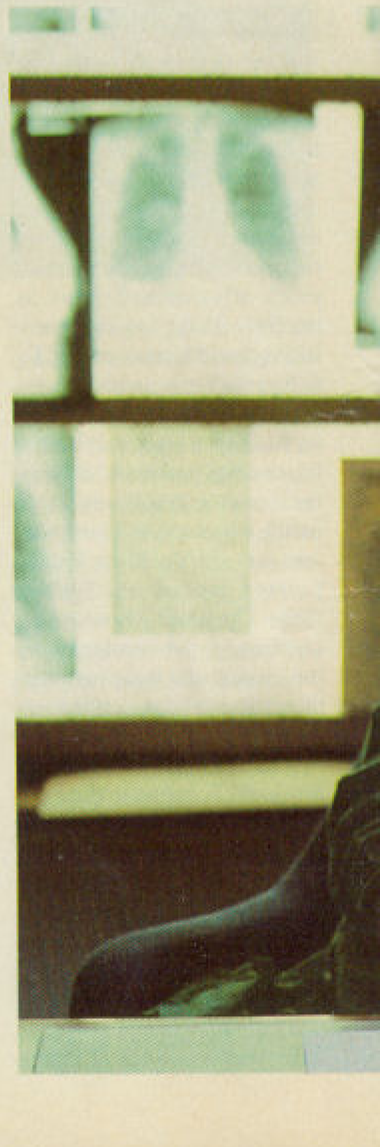
On a drizzly afternoon, Nordenström is sitting in his office, talking about cancer treatment and leafing through his book. He stops to point out before and after x-rays of tumors; he's talking about his successes and his failures. And he's talking about the danger of talking at all. Several years ago his work was written up in the *National Enquirer*, and he was plagued with telephone calls for months afterward. He realizes, however, that his theory, if it's of any value, must also provide routes for therapy. "I needed something that would attract people's interest," he says, "and cancer treatment is always interesting. It's for the layman or the ordinary doctor who wants to know what this is good for."

Then he begins to talk about some of his cases, pointing them out in his book. His first was in June 1978.

"This patient was too old to be operated on," he says. "She was 66. She had metastasis in the lung from an ovarian cancer. I introduced very tiny electrodes into the lung, and I gave this current here. This is the result—one month after treatment you can see a reaction around the tumor of some fibrous scar tissue. After seven months it starts to disappear. I only treated her once. It took about one hour, then she went home after the treatment. After five years she still had no recurrence. Then she died from the recurrence of her ovarian tumor, but I'm sure the lung tumor would have killed her first."

His second case: "A young girl, nineteen years of age. She had an unusual kind of malig-

Perhaps the key obstacle to the acceptance of Nordenström's theory is its challenging interdisciplinary nature.



nancy of the uterus. Surgeons cut out the uterus. Two years later she had four metastases in the lungs: two in the right, two in the left. The largest one was four centimeters in diameter. These tumors do not respond to radiotherapy—it's useless. The surgeons refused to operate, because she had tumors in both lungs. She got chemotherapy, but the tumors continued to grow. She lost her hair. It was bad. Then they said to me, 'Well, you can try.' I implanted electrodes, I treated all four tumors, one at a time. They all regressed. She's still in good health seven years after."

Nordenström began thinking about treating tumors back in 1965 when he first linked necrosis in a tumor with a change in electric potential. That internal necrosis represented half the process of healing, but only half, because the external tumor continued to grow. Nordenström considered what would happen if he stuck his electrodes into the tumor and added some external power to the electric circuit that had been switched on by the necrosis. If the circuit was related to the process of healing, he ought to be able to stimulate it further. It was all speculative, but . . .

By 1978, when he was ready to treat his first tumor, he had created a list of expectations of what his electricity ought to do if his thesis was right.

First, he figured that because white blood cells, the primary tumor-fighters of the body, carry negative electric charge, he should be able to attract more of them to the tumor by placing a positive electrode directly in it—the physiological equivalent of luring more troops into the battle.

Second, although cancer cells multiply faster than normal cells, they are also more vulnerable. The theory behind chemotherapy is to change the environment sufficiently to kill the cancer cells without doing in the healthy ones. The electric field should likewise create changes in that environnment, one of which would be a chemical reaction around the electrode, like the acid build-up in an old battery.

Third, around the outside of the tumor, the acidic reaction would kill some of the red blood cells, or at least damage their hemoglobin, preventing delivery of oxygen to the tumor.

Fourth, the positive electric field should move water out of the tumor, shrinking it and causing the surrounding tissue to swell, putting pressure on the blood vessels and thereby blocking the flow of blood to the tumor.

Finally, the chemical reactions at the electrodes would produce a pocket of gas, which could create a high-pressure cavity that might actually break the tumor mechanically, from the inside out.

Nordenström's tumor-killing tactics sounded plausible. But he would need permission to try them on patients. The only ones the ethics committee at his hospital would allow him to treat were those who had refused, or failed to respond to, all other treatment. "I got only very, very poor cases, where no other therapy was available—large tumors growing everywhere," Nordenström says. Many patients were in such bad shape that even if he had been able to destroy their lung tumors, their cancer was spreading so fast they would probably have died soon anyway.

Nordenström put his electrodes in 20 patients in his first series of tests. He treated them for up to three hours, and then they went home. The treatment was as experimental as it could be. Even after testing it on animals, he was still guessing at how to administer the electricity and in what dosages. And still, in ten of his patients the tumors regressed, and in seven they disappeared entirely or simply died, remaining a lump of harmless tissue. Nordenström had achieved what doctors call clinical and therapeutic success.

In his next 25 patients, Nordenström stepped up the voltage from 10 volts to 20, but his success rate fell. He now believes that when he raised the voltage, he created a short-circuit between the two electrodes, which focused the electric field on only a small portion of the tumor. In his latest series of patients, he's starting with a lower voltage again, and building it up slowly. So far he's treated 80 patients, with no fatalities. If nothing else, the treatment is safe, and it seems to be a lot more than that.

Nordenström's Swedish colleagues are impressed. Folke Pettersson, chief of gynecological oncolgy at Karolinska Hospital, has referred half a dozen patients to Nordenström over the years, all cases that were either beyond hope or had refused surgery, and Nordenström's electricity has killed the tumors in most of them. "We are a few here who think he's a genius," Pettersson says. Elisabet Björkholm and Ingemar Näslund, both cancer specialists at Karolinska, have also sent patients to Nordenström, have seen his treatments, and are now believers. But both stressed that they did not want to raise false hopes. For now, at least, Nordenström's electric therapy works only on isolated tumors; the largest have been four centimeters across, and most smaller. It's not a miracle cure.

In the U.S., Nordenström's cancer treatments still haven't brought him the attention he would like. Once again, the fault may lie in the lack of available information. Nordenström has only published the results from his first 20 patients, and that was in the second-to-last chapter of his book. Greenspan of Yale, who says he has read the book, is at best cautiously optimistic: "I've seen pictures of some of his clinical results where tumors have diminished in size, but I haven't heard him present a statistical study. As you know, occasionally tumors will decrease in size by themselves. My gut feeling is that's not the case here."

Figley has more reservations. "He's treated lung nodules with low-voltage continuous electricity and some have responded. That can hardly be the approach to the overall problem of lung cancer. It's an almost exhibitionist kind of way to go at it."

Nordenström is probably more aware than anyone else of the shot-in-the-dark aspect of his work. Even he seems a little surprised that he has had any successes. He compares his electrical treatment to radiotherapy: "Radiotherapy has been practiced for eighty-five years at least, all over the world, extensively, every day, year after year. Still we don't know how to optimize that technique. And that's a fairly simple principle. With electricity you can play with an enormous number of parameters. In order to make sense of it, we ought to have large numbers of comparable tumors, sizes, treatments, total currents, locations, etc. It would take years and years, even if we start to work now all over the world."

Nordenström and his wife, Gerd, live near Stockholm in the village of Rönninge.

At present, Nordenström is treating only lung and breast cancers, because he's most familiar with them. But he sees no reason why electricity shouldn't work on tumors elsewhere in the body. He's also developing techniques for combining electrical treatment with chemotherapy, using the electrodes to concentrate the chemical around the tumor. So far, he has used the treatment on only two patients. Both have responded well.

Nordenström also has a backlog of basic research waiting for him. He's working on measuring the potentials created in bone fractures—one of the classic areas in which researchers have attempted to speed healing with electricity. Backed by his studies of the physiology of fractures, Nordenström hopes he'll obtain better results than his predecessors. "Everybody can show that they have a case here and there where electrical treatment seemed to have accelerated the healing," he says, "but it's like shooting into the woods. They hit something by chance. You must be able to predict what's happening. That's science."

Without some kind of dramatic coup, acceptance of Nordenström's work could take decades. Traditionally, a researcher of his stature is expected to take on and train young post-docs—freshly minted Ph.D.s or M.D.s—in his methods and his ideas. These disciples then go out into the scientific world and spread the word. But until his book was published Nordenström had no disciples. (Now he says he's working with a number of researchers in the Stockholm area, and would welcome more if they were ambitious and talented enough.)

While the pay-offs for following Nordenström may be enormous if his theory turns out to be correct, few young researchers are ready to risk their careers by running off to Sweden to pursue anything so far out of the mainstream of medicine. Even if Nordenström is right, taking up his work could still lead to a career of fighting the establishment. For an ambitious young radiologist, working on a new technology like magnetic resonance imaging, by comparison, offers a guarantee of publishing papers and making a name in the field. (At one point Nordenström tried to talk his eldest son, a surgeon, into helping him with his experiments. The son replied, "If I become a radiologist and succeed, it will be your merit. If I fail, it will be my fault." He stayed in surgery.)

If young researchers are hesitant to join Nordenström, their elder colleagues are even more so. Few established researchers are ready to give up everything on which they've built their reputations in order to duplicate another researcher's work. Even Nordenström's admirers, like Greenspan, are reluctant to commit themselves. Asked why he hadn't taken aside a post-doc in his department and suggested he study biological circuits, he replied vaguely, "I don't know; maybe I should." When Judah Folkman, a world-famous cancer researcher at the Children's Hospital in Boston, read Nordenström's book and heard him lecture, he thought the results were tantalizing, and had extraordinary potential. But, he said, "we didn't start working on it, because we were so busy with our own things, and we'd have to train somebody, and we assumed other people would get into it." When Bernard Watson, a professor of applied medical electronics at St. Bartholomew's Hospital in London, tried to get clinicians interested in using Nordenström's cancer treatments, they all turned him down. They seemed afraid to go before the ethics committees with a treatment that was so difficult to understand.

Phillip Chen, associate director for intramural affairs at NIH, says that Nordenström has to become an entrepreneur if he expects to get his work accepted. "If I were Nordenström," says Chen, "I would start padding around talking to administrators at NIH, at the American Cancer Society, at foundations. At this point it's more a matter of salesmanship than just being a quiet author somewhere."

> **People who have learned something as truth don't particularly like to hear that it may not be correct**

At 65, however, Nordenström isn't about to become a salesman. Although he'll give up his remaining administrative duties next year, he intends, in his words, to continue his research until he drops.

Those who are optimistic about the long-term survival of Nordenström's theory tend to be pessimistic about the malleability of the minds of their colleagues. "Perhaps," says Greenspan, "after he's long gone and I'm long gone, he'll be proved to be correct."

Pettersson points out, cynically, that medical researchers, like everybody else, tend to move in faddish flocks—espousing interferon one year, magnetic resonance imaging the next—and if something isn't backed by an enormous flow of money and a good press, they tend to ignore it. Greenspan points out that if Nordenström is right—if biologically closed electric circuits do exist in the body and play as key a role as he says they do—there will be quite a few red faces among medical researchers. "People who have learned something as the truth," he says, "don't particularly like to hear that they've based a large part of their careers on things that were either incomplete, or not completely correct."

While Nordenström tries to play down his cancer treatments, his entire theory is likely to live and die by how the medical community chooses to receive them. NIH's Doppmann points out that when Steven Rosenberg, a researcher at the National Cancer Institute, cured a seemingly hopeless case of cancer with a new drug called interleukin-2, he made it onto the cover of *Newsweek* within weeks. "People are looking for cancer cures," Doppman says. "If Nordenström is really making tumors disappear that haven't responded to anything else, he's going to be noticed." ◻